OUR ASTRONOMICAL COLUMN.

Astronomical Occurrences in October.

Oct. 1. 11h. 14m. to 11h. 53m. Moon occults B.A.C. 1240 (mag. 5·7).
3. 17h. 10m. to 18h. 9m. Moon occults 71 Orionis (mag. 5·1).
11. 11h. 2m. Minimum of Algol (β Persei).
13. Ceres 7′ S. of γ Ceti (mag. 3).
13. 7h. Venus in conjunction with δ Scorpii. Venus 10′ N.
14. 7h. 51m. Minimum of Algol (β Persei).
15. Venus. Illuminated portion of disc = 0·705.
15. Mars. Illuminated portion of disc = 0·951.
17. 5h. 2m. to 5h. 38m. Moon occults ξ Ophiuchi (mag. 4·5).
19–21. Epoch of the Orionid meteors (radiant 91° + 15°).
22. 9h. 5m. to 9h. 7m. Moon occults c' Capricorni (mag. 5·2).
23. 4h. 44m. to 7h. 38m. Transit of Jupiter's Sat. IV.
23. 8h. 53m. to 10h. 6m. Moon occults κ Aquarii (mag. 5·5).
24. 14h. 35m. to 15h. 30m. Moon occults λ Piscium (mag. 4·7).
27. 2h. 25m. to 4h. 6m. Partial eclipse of the moon. Our satellite will rise at 4h. 35m., 29m. after the earth's shadow has passed off her disc, but the penumbra will remain until 5h. 26m., though it will be observed with difficulty.
28. Ceres in opposition to the sun (Ceres, mag. 7·4).
31. 12h. 44m. Minimum of Algol (β Persei).

Fireball of September 14, 1901.—Mr. W. F. Denning writes:—

"One of those brilliant fireballs which often appear suddenly n the early part of the night, and for a few seconds illumine the sky and landscape, was seen by many persons in various parts of the country on September 14 at about 8h. 44m. It was especially bright over the western part of England, and people in South Wales and North Devon obtained a fine view of the phenomenon. As seen from these parts, the fireball was many times brighter than Venus, and it moved with moderate slowness, leaving a strong trail or train of sparks, which, however, quickly died out. The head was bluish-white, and it seemed to plough its way through the atmosphere with an irregular motion and fluctuating light, as though strongly resisted.

"The fireball was well observed at Manchester, Wallingford (Berks), Chiddingfold (Surrey), Bristol and many other stations. The direction of its flight from the best descriptions was from between the constellations Aquarius and Pegasus, the radiant being at 345° + 1° near the star β Piscium. The height of the meteor when first seen was 66 miles vertically over a point 6 miles N.E. of Ilfracombe, North Devon, and when last seen the height was about 26 miles over a point in the sea 3 miles N.W. of St. David's Head, Pembrokeshire. The length of path was 83 miles and velocity about 20 miles per second. Possibly the path may have been longer and the object may have approached to within about 23 miles of the earth's surface, but the observations are not quite accordant. It is to be hoped that further descriptions of this splendid object will be forthcoming, so that the real path may be very accurately ascertained.

"On September 14, 1875, at 8h. 27½m., a large fireball passed over the eastern counties of England, falling from a height of 63 to 14 miles and directed from a radiant at 348° ± 0°. Lieut.-Colonel Tupman computed the real path from twelve accordant observations, and there is no doubt that this brilliant object, which appeared exactly twenty-six years ago, belonged to the same system as that which furnished the recent fireball. Apart from the large meteors which are often directed from it, the radiant is well defined every year from ordinary shooting stars, and it appears that its chief activity is displayed during the months of August and September."

New Variable Star 77, 1901, Herculis.—Dr. T. D. Anderson announces that he has detected variability in the star B.D. + 7°·3199, the position of which is

R.A. = 16h. 25m. 49·7s.
Decl. = + 7° 8′·9.

Some years ago it was estimated to be about the ninth magnitude, while on August 19 and 21 it was invisible in a 3-inch finder with which tenth magnitude stars were easily visible.

THE GLASGOW MEETING OF THE BRITISH ASSOCIATION.

SECTION E.

GEOGRAPHY.

Opening Address by Hugh Robert Mill, D.Sc., LL.D., F.R.S.E., F.R.G.S., President of the Section.

On Research in Geographical Science.

Introductory.

The annual reassembling of friends and fellow-workers in the old re-visited towns, and the annual accession of new lovers of science, furnish a unique opportunity for a survey of the advances made in each department, a fitting occasion also for remembering those who have finished their work and can aid our deliberations only by the memory of their example.

Apart from our more intimate losses in the death of many distinguished geographers and devoted workers, the period since our last meeting has been for all a year of mourning. The passing of the nineteenth century was almost like the death of a friend, and it is still difficult to realise that the century which we had been so long in the habit of associating with everything new and great and progressive has itself become part of the past. Few coincidences have been more striking than the almost simultaneous close of that unparalleled reign which gave a name to the Era including all that was best and most characteristic of the century. The death of Queen Victoria carried so keen a sense of personal loss into every heart that few attempts have been made to show how vast a portion of the stream of time—measured by progress—intervened between the terminal dates of her life. Think for a moment of the splendid advances in the one small department of geographical exploration during the late Queen's reign, the multitude of landmarks which have been crowned by the great name of Victoria—of the Earth's most southerly land and its most northerly sea, of the largest lake and most majestic waterfall of Africa, the loftiest lake of Asia, the highest peak in New Guinea, the widest desert and most populous colony in Australia, and of the two thriving seaports on either side of the North Pacific which couple together the British Dominions of western America and eastern Asia.

What could be more appropriate in this first meeting after the close of such a century and of such a reign than to pass in brief but appreciative review the advances of geography during those hundred or those sixty-five years? One thing in my opinion is more appropriate than to dwell on past triumphs or to regret past greatness, and that is to survey our present position and look ahead. In the first year of a new century and of a new reign we are reminded that we have a future to face and that the world is before us, and I propose to seize this opportunity in order to speak of the science of geography as it is now understood and especially to urge the importance of the more systematic pursuit of geographical research henceforward.

Geography in the Universities.

The prospect of immediate expansion in many British universities seems at last likely to afford more than one opportunity of wiping out the old disgrace of the neglect of geographical science in the accredited seats of learning. Already Oxford has a well-manned School of Geography, and Cambridge has a Reader in Geography. The reconstituted University of London occupies the best position in the world for creating a chair of geographical research, situated as it is in the very centre of the comings and goings of all mankind, and in touch with the most complete geographical library and map-collection in existence. The new University of Birmingham may, it is hoped, prove better than its promises, and may perhaps after all provide some more adequate treatment of geography than its proposed partition amongst the professors of half a dozen special subjects, all of them concerned in geography, it is true, but none of them individually, nor all of them collectively, capable of embodying that coordination of parts into a harmonious unity which gives to geography its power as a mental discipline and its value for practical application. But England in all that pertains to higher education is still a poor country, and the will to do well is hampered by the grinning demon of poverty. Here, on the other side of the Border, we are in a different atmosphere. The wave of the magician's wand in the hands of Andrew Carnegie has brought wealth that last year would have been deemed fabulous to the ancient universities in Scotland, and it will be a

disgrace to our country if this splendid generosity does not result in the establishment of one or more fully endowed and completely equipped chairs of geography.

There may still be some people who view geography as the concern only of soldiers and sailors, adventurous travellers, and perhaps of elementary teachers. Exploration is undoubtedly the first duty of geographers, but it is a duty which has been well done, the nineteenth century having left us only one problem of the first magnitude. This is the exploration of the polar regions, and even here the twentieth century clamours for new methods.

The Antarctic Expeditions.

This year has seen the long-hoped-for Antarctic expeditions set out on their great quest, a quest not only of new lands in the southern ice-world but of scientific information regarding all the conditions of the vast unknown region. Two expeditions have been planned in Great Britain and Germany with a complete interchange of information regarding equipment and methods of work. Provision has been made for simultaneous magnetic and meteorological observations, and in some instances for the use of instruments of identical construction, and all possibility of any unseemly rivalry in striving for the childish distinction of getting farthest south has been obviated by the friendly understanding that the British ship shall explore the already fairly known Ross quadrant, where it is pretty sure that extensive and accessible land will favour exploration by sledges, while the Germans have chosen the entirely unknown area of the Enderby quadrant which no ice-protected steamer has yet attempted to penetrate, and where they enter a region of potential discovery before they cross the Antarctic circle.

The British expedition is equipped on the good old plan that produced such fine results in the days of Cook and Ross; it is manned by sailors of the Royal Navy and is under the command of a gallant naval officer, though, unlike the earlier vessels, the *Discovery* is not herself a naval ship. As in the days of Cook the naval officers are assisted in their non-professional work by several young and promising scientific men, two of whom have already had experience of work in the polar regions. These have the great advantage of the counsel and help of Mr. George Murray, of the British Museum, who goes as far as Melbourne in the position of Director of the Scientific staff.

No one who has seen the zeal and unflagging enthusiasm with which Sir Clements Markham has organised the expedition can hesitate to accord to him in fullest measure the credit for its successful inauguration. And no one who has seen the quiet and good-humoured determination of the commander, Captain R. F. Scott, in overcoming many irritating preliminary difficulties, can doubt his fitness to undertake the heavy responsibilities of the voyage. I at least am sure that he will be a worthy successor to Cook, Ross, Franklin, Nares, and all the other officers who have made their names and the name of the British Navy famous in polar service. The second in command, Lieutenant Armitage, R.N.R., has had several years of Arctic experience, and amongst the crew there are some old whalers whose knowledge of the ways of sea-ice should prove of value. The ship and her equipment are unique; it is no exaggeration to say that she is the best-found and most comfortable vessel which has ever left our shores on a voyage of discovery.

The German expedition has been more boldly planned than ours. It is new and experimental all through, as befits a young nation in its first exuberant efforts in a new field. If some people suppose that it may have made mistakes that our expedition has avoided, these, at least, are new mistakes from which new lessons are to be learned. If risks must be run—and we of the twentieth century are, I trust, no more timid of incurring risks than our predecessors of the nineteenth, or the eighteenth, or even the seventeenth—it is good that they should be new risks. To scientific men in Germany it appears natural and reasonable that a man of science should be the head of a scientific expedition; and that a geographer should lead a geographical expedition. Many British men of science sympathise in this view. Dr. Erich von Drygalski, one of the professors of Geography in the University of Berlin, has been entrusted with the command to which he was appointed before the ship was designed, and for five years he has given all his time and thought to the expedition. He is supported by a band of highly trained specialists, who have spared neither time nor travel in mastering the subjects with which they may deal, and each has also received a general training in the subjects of all his colleagues—an admirable precaution. The captain of the *Gauss*, who belongs to the Merchant Service, has taken a course of training from the Norwegian whalers off Spitsbergen. He will, of course, be absolute master of the ship and crew in all that concerns order and safety, but he will be under the direction of the leader in all that concerns the plan of the voyage and the execution of scientific work. This arrangement is one which has always seemed to me to be desirable, that the captain of a ship on scientific service should occupy a position in relation to the scientific chief similar to that of the captain of a yacht in relation to the owner; but it is subject to the drawback that a naval officer could not well be asked to accept such a divided command.

But whatever our views as to ideal organisation may be, we are all certain that both expeditions will do the utmost that they can to justify the confidence that is placed in them and to bring honour to their flags. We know that the officers and staff of the *Discovery* belong to a race which, whether trained in the University or in the Navy, has acquired the habit of bringing back splendid results from any quest that is undertaken.

A Definition of Geography.

The bright prospects of Antarctic Exploration must not, however, blind us to the fact that exploration is not geography, nor is the reading or even the writing of text-books, nor is the making of maps, despite the recognition of leading cartographers as "Geographers to the King." These are amongst the departments of geography, but the whole is greater than its parts.

The view of the scope and content of Geography which I have arrived at as the result of much work and some little reading during twenty years is substantially that held by most modern geographers. But it is right to point out that the mode of expressing it may not be accepted without amendment by any of the recognised leaders of the science, and for my own part I believe that discussion rather than acceptance is the best fate that can befall any attempt at stating scientific truth.

Put in the fewest words, my opinion is that

Geography is the science which deals with the forms of relief of the Earth's crust, and with the influence which these forms exercise on the distribution of all other phenomena.

This definition looks to the form and composition of the Earth's crust itself, and to the successive coverings, partial and complete, in which the stony globe is wrapped. We sometimes hear of the New Geography, but I think it is more profitable to consider the present position of Geography as the outcome of the thought and labours of an unbroken chain of workers, continuously modified by the growth of knowledge, yet old in aim, old even in the expression of many of the ideas that we are apt to consider the most modern.

Some Historical Landmarks.

Claudius Ptolemæus, about 150 A.D., gathered into his great "Geography" the whole outcome of the Greek study of the habitable world. He laid stress on the threefold nature of descriptions of the Earth's surface, the general sketch of the great features of the world alone receiving the name of Geography, the more special description of an area he termed Chorography, and the detailed account of a particular place Topography.

Aristotle, who first adduced real proofs of the sphericity of the Earth, had not failed to note the relationships which exist between plants and animals, and the places in which they are found, and he argued that the character of peoples was influenced by the land in which they lived; but Ptolemy cared little for theories, comparisons, or relationships, confining himself rather to the record of actual facts. He made errors, the results of which were more important, as it happened, in advancing knowledge than were the truths which he recorded; for after the troubled mediæval sleep, when even the spherical form of the Earth was blotted out of the knowledge of Christendom, the scientific deductions made by Toscanelli from the false premises of Ptolemy heartened Columbus for his westward voyage to the Indies, on the very outset of which he stumbled all unknowing on the New World. When Magellan succeeded in the enterprise which Columbus had commenced, the fourteen centuries' reign of Ptolemy in geography came to an end; his work was done.

The rapid unveiling of the Earth in the sixteenth and seventeenth centuries cast a glamour over feats of exploration which has not yet been wholly dissipated, and it may not be easy, even now, to obtain wide credence for the fact that the explorer is usually but the collector of raw material for the geographer.

It is of vital interest to trace the re-formation of the theory of geography after its interruption in the Middle Ages. The fragments of the old Greek lore were cemented together by new and plastic thoughts, crudely enough by Apian, Gemma Frisius, and Sebastian Munster in the sixteenth century, but with increasing strength and completeness by Cluverius, Carpenter, and Varenius in the seventeenth.

The First Oxford Geographer.

The names of Cluverius and Varenius are familiar to every historian of geography, but that of Carpenter, I am afraid, is now brought to the notice of many geographical students for the first time. He was not so great as Varenius, but he was the first British geographer to write on theoretical geography as distinguished from mathematical treatises on navigation or the repetition of narratives of travel, and I think that there is evidence to show that his work had an influence on his great Dutch contemporary.

Nathanael Carpenter, Fellow of Exeter College, Oxford, published his book in 1625 under the title—

"Geographie delineated forth in two Bookes. Containing the Sphericall and Topicall parts thereof," and with the motto from Ecclesiastes on its title-page—

"One generation commeth, and another goeth, but the Earth remayneth for ever."

The great merits of Carpenter's treatise are his firm grasp of the relation of one part of geography to another, his skilful blending of the solid part of the work of Aristotle and Ptolemy with that of the explorers and investigators of his own generation, and the wholesome common-sense that dominates his reasoning. His definition is comprehensive and precise.

"Geographie is a science which teacheth the description of the whole Earth. The Nature of *Geographie* is well expressed in the name: For *Geographie* resolved according to the *Greeke* Etymologie signifieth as much as a description of the Earth; so that it differs from *Cosmographie*, as a part from the whole. Forasmuch as *Cosmographie* according to the name is a description of the whole world, comprehending under it as well *Geographie* as *Astronomie*. Howbeit, I confesse, that amongst the ancient Writers, *Cosmographie* has been taken for one and the self-same science with *Geographie* as may appeare by sundry treatises meerely Geographicall, yet intituled by the name of *Cosmographie*."

The differences held by Ptolemy to distinguish geography from chorography Carpenter shows to be merely accidental, not essential, and as to geography he says "It is properly tearmed a *Science*, because it proposeth to it selfe no other end but knowledge; whereas those faculties are commonly tearmed *Arts*, which are not contented with a bare knowledge or speculation, but are directed to some farther work or action. But here a doubt seems to arise, whether this *Science* be to be esteemed *Physicall* or *Mathematicall*? Wee answer, that in a Science two things are to bee considered: first, the *matter* or object whereabout it is conversant; secondly, the *manner* of handling and explication: For the former no doubt can bee made but that the object in *Geographie* is for the most part *Physicall* consisting of the parts whereof the Spheare is composed; but for the manner of Explication it is not *pure* but *mixt*; as in the former part *Mathematicall*, in the second rather *Historicall*; whence the whole Science may be alike tearmed both *Mathematicall* and *Historicall*; not in respect of the *subject* which we have said to be *Physicall* but in the manner of *Explication*."

Although somewhat diffuse in expression, the meaning of these statements is clear and sound, and to the British public as new now as it was in the days of King Charles. The book treats of mathematical geography and cartography, of magnetism, climates, the nature of places, of hydrography, including the sea, rivers, lakes and fountains, of mountains, valleys and woods, of islands and continents, and at considerable length of people and the way in which they are influenced by the land in which they live. Whether Dr. Carpenter lectured on geography in Oxford I do not know, but his book must have acquired a certain currency, for a second edition appeared in 1635, and it seems probable that it was known to Varenius.

Varenius and Newton.

Varenius, a young man who died at twenty-eight, produced in Latin a single small volume published in 1650, which is a model of conciseness of expression and logical arrangement well worthy even now of literal translation into English. So highly was it thought of at the time that Sir Isaac Newton brought out an annotated Latin edition at Cambridge in 1672.[1] The opening definition as rendered in the English translation of 1733 (a work spoilt in most places by a parasitic growth of notes and interpolations) runs:—

"Geography is that part of *mixed mathematics* which explains the state of the earth and of its parts, depending on quantity, viz. its figure, place, magnitude and motion with the celestial appearances, &c. By some it is taken in too limited a sense, for a bare description of the several countries; and by others too extensively, who along with such a description would have their political constitution."

Varenius produced a framework of Physical Geography capable of including new facts of discovery as they arose, and it is no wonder that his work, although but a part, ruled unchallenged as the standard text-book of pure geography for more than a century. He laid stress on the causes and effects of phenomena as well as the mere fact of their occurrence, and he clearly recognised the vast importance upon different distributions of the vertical relief of the land. He did not treat of human relations in geography, but, under protest, gave a scheme for discussing them as a concession to popular demands.

Kant.

As Isaac Newton, the mathematician, had turned his attention to geography at Cambridge in the earlier part of the eighteenth century, so Immanuel Kant, the philosopher, lectured on the same subject at Königsberg in the later part. The fame of Kant as a metaphysician has defrauded him of much of the honour that is his due as a man of science. As Prof. Hastie puts it: "His earlier scientific work, like an inner planet merged in light, was thus almost entirely lost sight of in the blaze of his later philosophical splendour."

Kant, it will be remembered, considered that the communication of experience from one person to another fell into two categories, the historical and the geographical: that is to say, descriptions in order of time or in order of space. The science of geography he considered to be fundamentally physical, but physical geography formed the introduction and key to all other possible geographies, of which he enumerated five: *mathematical*, concerned with the form, size, and movements of the earth and its place in the solar system; *moral*, taking account of the customs and characters of mankind according to their physical surroundings; *political*, concerning the divisions of the land into the territories of organised governments; *mercantile*, or, as we now call it, commercial geography; and *theological*, which took account of the distribution of religions. It is not so much the cleavage of geography into five branches, all springing from physical geography like the fingers from a hand, which is worthy of remark, but rather the recognition of the interaction of the conditions of physical geography with all other geographical conditions. The scheme of geography thus acquired a unity and a flexibility which it had not previously attained, but Kant's views have never received wide recognition. If his geographical lectures have been translated no English or French edition has come under my notice, and such currency as they obtained in Germany was checked by the more concrete and brilliant work of Humboldt, and the teleological system elaborated in overwhelming detail by Ritter.

The teleological views of Ritter were substantially those of Paley. The world, he found, fitted its inhabitants so well that it was obviously made for them down to the minutest detail. The theory was one peculiarly acceptable in the early decades of the nineteenth century, and it had the immensely important result of leading men to view the earth as a great unit with all its parts coordinated to one end. It gave a philosophical, we may even say a theological, character to the study of geography.

Kant's views had pointed to such a unity, but from another side, that of evolution. It was not till after Charles Darwin had fully restored the doctrine of evolution to modern thought that it was forced upon thinking men that the fitness of the earth to its inhabitants might result, not from its being made for them, but from their having been shaped by it. It is certain that the influence of the terrestrial environment upon the life of

[1] Dugdale, in the introduction to the English translation published in 1733, states explicitly that Newton produced his version for the benefit of the students attending his lectures "on the same subject" from the Lucasian chair; but we have been unable to find any more satisfactory evidence that Newton actually lectured on geography at Cambridge.

a people has been carried too far by some writers—by Buckle, in his "History of Civilisation," for example—but it is no less certain that this influence is a potent one.

The Nature of Geography.

Granted that such influence is exercised, some objectors may urge that geography has nothing to do with the matter, and we are compelled to acknowledge that the meaning and contents of geography are in this country as variously interpreted as the colour of the chameleon in the traveller's tale. Yet my thesis is that it is just this relation between the forms of the solid crust of the Earth and all the other phenomena of the surface that constitutes the very essence of geography.

It is a fact that many branches of the study of the Earth's surface which were included in the cosmography of the sixteenth century, the physiography of Linnæus, the physical geography of Humboldt, and perhaps even the *Erdkunde* of Ritter, have been elaborated by specialists into studies which, for their full comprehension, require the whole attention of the student. Geology, meteorology, oceanography and anthropology, for example, have been successively specialised out of geography; but it does not follow that these specialisations fully occupy the place of geography, for that place is to coordinate and correlate all the special facts concerned so that they may throw light on the plan and the processes of the Earth and its inhabitants. Geography, in fact, is concerned with the results, not with the processes of the special sciences, and the limits between geography and geology, to take a single instance, are to be drawn, not between any one class of phenomena and another, but between one way and another of marshalling and utilising the same facts. This was clear to Carpenter in 1625, though we have almost forgotten both it and him.

The Principles of Geography.

The principles of geography—the "pleasant principles," to use the phrase of old William Cuningham in 1559—on which its claims to status as a science rest are generally agreed upon by modern geographers, though with such variations as arise from differences of standpoint and of mental process. The evolutionary idea is unifying geography as it has unified biology, and the whole complicated subject may be presented as the result of continuous progressive change brought about and guided by the influence of external conditions. These views have been often expressed in recent years, but they do not seem to have been very seriously considered, and no excuse need be offered for presenting them once more, though in an epitome curt to baldness.

The science of geography is of course based on the mathematical properties of a rotating sphere; but if we define geography as the exact and organised knowledge of the distribution of phenomena on the surface of the Earth, we see the force of Kant's classification, which subordinated mathematical to physical geography. The vertical relief of the Earth's crust shows us the grand and fundamental contrast between the oceanic hollow and the continental ridges; and the hydrosphere is so guided by gravitation as to fill the hollow and rise upon the slopes of the ridges to a height depending on its volume, thus introducing the great superficial separation into land and sea. The movements of the water of the ocean are guided in every particular by the relief of the sea-bed and the configuration of the coast lines. Even the distribution of the atmosphere over the Earth's surface is affected by the relief of the crust, the direction and force of the winds being largely dominated by the form of the land over which they blow. The different physical constitution of land, water and air, especially the great difference between the specific heat and conductivity or diathermancy of the three, causes changes in the distribution of the sun's heat, and as a result the simple climatic zones and rhythmic seasons of the mathematical sphere are distorted out of all their primitive simplicity. The whole irregular distribution of rainfall and aridity, of permanent, seasonable and variable winds, of sea-climate and land-climate, is the resultant of the guiding action of land forms on the air and water currents, disturbed in this way from their primitive theoretical circulation. So far we see the surface forms of the Earth, themselves largely the result of the action of climatic forces, and constantly undergoing change in a definite direction, controlling the two great systems of fluid circulation. These in turn control the distribution of plants and animals, in conjunction with the direct action of surface relief, the natural regions and climatic belts dictating the distribution of living creatures. A more complicated state of things is found when the combined physical and biological environment is studied in its incidence on the distribution of the human race, the areas of human settlement, and the lines of human communications. The complication arises partly from the fact that each of the successive earlier environments acts both independently and collectively; but the difficulty is in greater degree due to the circumstance that man alone amongst animals is capable of reacting on his environment and deliberately modifying the conditions which control him.

It seems to me that the glory of geography as a science, the fascination of geography as a study, and the value of geography in practical affairs are all due to the recognition of this unifying influence of surface relief in controlling, though in the higher developments rather by suggestion than dictation, the incidence of every mobile distribution on the Earth's surface.

The Classification of Geography.

Following out this idea, we are led to a classification of the field of geography in a natural order, in which every department arises out of the preceding with no absolute line of demarcation, and merges into the succeeding in the same way. This classification, it is necessary to note, is not like a series of pigeon-holes, which may be placed in any arbitrary order, but like a chain, in which the succession of the links is essential and unalterable.

Since form and dimension are the first and fundamental concepts in geography, the first and basal division is the *Mathematical*. Mathematical geography leaves the Earth as a spinning ball lighted and warmed according to a rigid succession of diurnal and annual changes. This merges into the domain of *Physical Geography*, which involves the results of contemporary change in the crust and the circulation of the fluid envelopes, with the resulting modifications in the simple and predictable mathematical distributions. This division falls naturally into three parts: Geomorphology, dealing with the forms of the solid crust and the changes they are undergoing at the present time; Oceanography, dealing with the great masses of water in the world; and Climatology, dealing with the effects of solar energy in the air. But all three spheres—lithosphere, hydrosphere, and atmosphere—are so closely inter-related that no one of them can be studied without some preliminary knowledge of the others. This forms the largest and most important part of geography, more varied and intricate than the mathematical, better known and more definite than those involving life.

Bio-geography, the geographical distribution of life, arises directly from physical geography, which dominates it, but it is full of complex questions which involve the biological nature of the organism and the influence of physical environment, in which geographical elements, although predominant, do not act alone. Difficult as some of the problems of the distribution of life are at the present day, the remains of living creatures found fossil in the rocks, and the survivors of archaic forms still lingering in remote islands, supply us with our only instrument of research into the geography of past ages, often making it possible to lay down the areas of land and water in earlier geological periods.

The relation of man to the surface of the Earth detaches itself from the rest of Bio-geography by the number of exceptions to general laws of distribution and by the human power of modifying environment. It has necessarily been formed into a special department, *Anthropo-geography*. In primitive man the control exercised by environment is nearly as complete and simple as in the case of the lower animals; but with every advance in culture fresh complications are introduced. The relation of people to the land they inhabit, the choice of sites for dwellings and towns, the planning and carrying into effect of lines of communication, are all obviously much under the control of land form and climate. When people get settled in a favourable position they usually become attached to it; they acquire, one may say, the colour of the land, in modes of thought as well as in manner of life. The poems of Ossian and the Crofter Question require for their elucidation a knowledge of the geographical conditions of the Western Highlands, just as the Border ballads and the Border raids were largely conditioned by the geography of the Southern Uplands.

Attachment to the native valley or the native fields leads to the holding of land by clans or tribes and the fusion of tribes into nations, while changes in physical conditions stimulating migration from a deteriorating country may lead to the invasion

of settled territories by homeless hordes. Here Anthropo-geography buds off the subdivision of *Political Geography*, which takes account of the artificial boundaries separating or sub-dividing countries, and of the innumerable artificial restrictions and ameliorations which are superimposed on the natural barriers and channels of intercommunication. Even in political geography only a humble place is held by a statement of boundaries and capitals, to lists of which the great name of Geography has actually been confined by people who ought to have known better.

Anthropo-geography views the world from the standpoint of the race, political geography from the standpoint of the nation; but room has to be found for a yet more restricted outlook, that of the individual, whose view of the world as it profits himself is known as commercial geography. This department deals with natural commodities and their interchange, and perhaps because here rather than in the other departments a successful comprehension of the inter-relation of cause and effect may be, in the language of the schoolroom, "reduced to pounds, shillings and pence," the name of Applied Geography has been proposed. It fitly terminates our survey of the science, for the flickering disturbances of the equilibrium of supply and demand known simultaneously over the whole world, and the slower movements of transport to restore equilibrium, are still far from the power of scientific prevision, and all we can do at present is to point out certain clear lines of least resistance, or greatest advantage, due to the interactions of natural and human causes and effects.

To sum up in a sentence the field and the function of geography in the broad majesty of its completeness, we may say that it is the description of the surface of the solid Earth as it is in itself, as it acts upon the ocean, the air, and the living things which inhabit it, and as it is affected in turn by their actions.

Geography and the State.

Viewed thus, I believe that geography will be found to afford an important clue to the solution of every problem affecting the mutual relations of land and people, enlightening the course of history, anticipating the trend of political movements, indicating the direction of sound industrial and commercial development.

It would be possible, unfortunately it would be easy, to enumerate misconceptions of history, blunders in boundary settlements, errors in foreign policy, useless and wasteful wars, mistakes in legislation, failures in commercial enterprise, lost opportunities in every sphere, which are due to the neglect of such a theoretical geography. Surely it is to the laws defining the interaction of Nature and Man that we should turn for guidance in such affairs rather than to the dull old British doctrine of "muddling through." That vaunted process after all means that we are driven by stress of facts to do without intending it or knowing how, and at immense expense, the very things that intelligent study beforehand would have shown to be necessary, feasible and cheap.

All this has been urged again and again, and it has fallen on the ears of those in authority "like a tale of little meaning, though the words are strong." I admit that all advocates of a rational geography have not escaped the danger of the special pleader—they have promised too much. If a Government official were to say, "Yes, I confess there was a mistake here, the affair was managed badly, much money and some prestige were lost; it must all be done over again; please tell me how," I am afraid that the chances are that the answer would be vague, general and unpractical. If the answer to this boldly hypothetical question is ever to be clear and definite, geography must be studied as it has never yet been studied in this country. It must pass beyond the stage of a pastime for retired officers, colonial officials and persons of leisure, and become the object of intense whole-hearted and original study by men of no less ability who are willing to devote, not their leisure, but their whole time to the work. The object of geographical research should be nothing less than the demonstration or refutation of what we claim to be the central principle of geography—that the forms of terrestrial relief control all mobile distributions.

A Projected Geographical Description.

In order to focus the question it may be convenient to consider the geography—or chorography, as Ptolemy would have termed it—of the British Islands. No author has ever attempted to give such a description. Camden's "Britannia" was swamped by archæology; the county histories, which are certainly not deficient in number, were wrecked outward bound on the harbour-bar of genealogy. Sir John Sinclair's old "Statistical Account of Scotland" in the intelligent utilisation of very incomplete data was a great but solitary stride in the right direction. Bartholomew's great "Atlas of Scotland" supplies the cartographical basis for a modern description of the northern kingdom; but the description itself has not been undertaken on an equal scale. The work of producing a complete geographical description of the British Islands would be gigantic, but not hopelessly difficult.

The material has been collected at an enormous expenditure of public money, and is stacked more or less accessibly, much of it well-seasoned, some I fear spoilt by keeping; but there it lies in overwhelming abundance, heaps of building materials, but requiring the labour of the builder before it can become a building.

There is first and chief the Ordnance Survey, one of the grandest pieces of work in mathematical geography that has ever been accomplished. The result is a series of maps almost as perfect as one can expect any human work to be, showing in a variety of scales from ¼ of an inch to 25 inches to a mile every feature of the configuration of the land—except the lake-beds.

There is next the hydrographic survey by the Admiralty, giving every detail of the subaqueous configuration in and around our islands—except the lake-beds.

These two great surveys supply the basis for a complete description of the British Islands, and the geological survey, which in a sense is more elaborate than either of the others, completes the fundamental part. The geological map makes it possible to explain many of the forms of the land by referring to the structure of the rocks which compose them. Both the geological and hydrographic surveys are accompanied by memoirs describing the features and discussing the various questions arising from the character of each sheet; but there is nothing of the kind for the maps of the ordnance survey.

The ordnance maps show at the date of their preparation the extent and also the nature of the woodlands and moorlands, and this information is supplemented by the Returns of the Board of Agriculture, which each year contain the statistics of farm crops, waste land, and livestock for every county. These returns are excellently edited from the statistical point of view, but they are not discussed geographically. It is easy to see in any year how much wheat is raised in each county, but it is a slow and laborious process to discover from the Returns what are the chief wheat-growing areas of the country. The county is too large a unit for geographical study, as it usually includes many types of land form and of geological formation. Before the distribution of crops can be understood or compared with the features of the ground they must be broken up into parishes, or even smaller units, and the results placed on maps and generalised. The vast labour of collecting and printing the data is undertaken by Government, and paid for by the people without a murmur, but the geographer is left in ignorance for the want of a comparatively cheap and simple cartographic representation of the facts.

The Inspector of Mines and the Board of Trade publish statistics of the industry and the commerce of the country, statistically excellent, no doubt, but in most cases lacking the cartographic expression which makes it possible to take in the general state of the country from year to year. The same is true of the Registrar-General's Returns of births, marriages, and deaths, in themselves an admirable epitome of the health conditions of the country, and of the fluctuations in population, but limited by a narrow specialism to the one purpose.

Finally and chiefly we have the Census Reports. Once in ten years the people are numbered and described by sex, age and occupation. The inhabited houses are numbered, and the smaller dwellings grouped according to size. The figures are most elaborately classified and discussed, so as to bring out the distribution of population, and its change from the previous decade. But to the geographer the Census Reports are like a cornfield to a seeker of bread. The grains must be gathered, prepared, and elaborated before the desired result is obtained. Nowhere is the cartographic method more useful than here. It is a striking contrast to turn to the splendid volumes of the United States Census Reports, many of them statistically inferior to ours, but thickly illustrated with maps, showing at a glance the distribution of every condition which is dealt with, and

enabling one to follow decade by decade the progressive development of the country, and to study for each census the relations between the various conditions.

These are only a few of the statistical publications, produced by Government, and embodying year after year a mass of conscientious labour, which, save for a few specialists who extract and utilise what concerns themselves, is annually "cast as rubbish to the void."

One small department supported by public money, but under unofficial direction, may be referred to as an example of the successful employment of cartographic methods. This is the Meteorological Council, appointed by the Royal Society, and charged with the collection of meteorological data and the publication of weather reports, forecasts, and storm warnings. The maps published twice daily to show the distribution of atmospheric pressure and temperature are only rough sketches and very much generalised, yet they serve the purpose of presenting the facts in a graphic form, yielding at a glance information which could only be extracted from tables by long and laborious efforts. The pilot charts, published monthly by the same department, showing the average conditions of air and sea over the whole North Atlantic, and the occasional atlases of oceanographical data are valuable geographical material.

The official work of Government is supplemented by the voluntary labours of many societies, in whose transactions much valuable material is stored, and in not a few cases is admirably discussed. But even with these supplements gaps remain which must be filled by private enterprise before a complete geographical description can be compiled.

Considering the Ordnance Survey alone it is hardly credible and not at all creditable that the Treasury should veto the extension of the survey to the lake-beds on the score of expense, yet such is the fact. The directors of the Survey have shown themselves ready to encourage private workers by placing the data presented by them upon the maps with due acknowledgment.

The Survey of the Lakes.

It is with profound satisfaction that I now make an announcement—by special favour the first public announcement—of a scheme of geographical research on a national scale by private enterprise. Sir John Murray and Mr. Laurence Pullar have resolved to complete the bathymetrical survey of all the fresh-water lakes of the British Islands. Mr. Laurence Pullar will take an active part in the proposed survey, and has made over to trustees a sum of money sufficient to enable the investigation to be commenced forthwith and to be carried through in a comprehensive and thorough manner. It is intended to make the finished work an appropriate and worthy memorial of Mr. Pullar's son, the late Mr. Fred Pullar, who had entered enthusiastically upon the survey of the lochs of Scotland, and whose heroic death while endeavouring to save life in Airthrey Loch last February must be present to the memory of many of you. Large sums of money devoted in good faith to scientific purposes do not always bring about the wished-for result; but in this case there is no room for anxiety on that score. Sir John Murray, with whom Mr. Fred Pullar had worked for several years, has generously promised to direct the whole scheme, and to be responsible for carrying it out. All the lakes of the British Islands will be sounded and mapped as a preliminary to the complete limnological investigation which is proposed. The nature of the deposits, the chemical composition of the water and its dissolved gases, the rainfall of the drainage areas, the volumes of the inflowing and outflowing streams, the fluctuations in the level of the surface, the seasonal changes of temperature, and the nature and distribution of aquatic plants and animals will all receive attention. The geological history of the lakes may also be inquired into with reference to such points as the growth of deltas, the erosion of the margins, and, perhaps, the conditions of the old dead lakes that are now level meadows.

Five years at least will be required to make these observations and to incorporate them in memoirs, each of which will be a complete natural history of the lakes of one river basin. The proposed work wants more than money, direction and time. It requires the services of several young and enthusiastic workers—preferably men who have completed their University course and are anxious to devote some time to research. Sir John Murray and Mr. Pullar wish to meet three or four capable young fellows, one preferably a chemist, one a geologist, one a botanist, and one a zoologist. When found they will be offered a salary sufficient to enable them to give their whole time to the work, but not large enough to induce anyone who has not the love of science at heart to take it up. From my experience when working in somewhat similar conditions at the Scottish Marine Station seventeen years ago, I can promise those who will have the good fortune to be selected plenty of hard work for which they will get the fullest credit—and this they will appreciate more keenly when they come to know the world better—and I can promise them also in their association with Sir John Murray a course of scientific and intellectual training such as even the universities do not afford.

Other Desirable Surveys.

The Geological Map requires to be supplemented by additional work on the nature of the superficial soil as it affects agriculture, such as is expressed in the *Cartes agronomiques* of France, going more fully into the chemical nature of the soil than is possible on the Drift Maps of the Survey which so usefully supplement the maps of solid geology. Such experiments as have been made at the College at Reading in collecting analyses of the soils in the neighbourhood might very well be carried out at the agricultural colleges and other centres all over the country. It would form an invaluable supplement to the work of the Government geologists.

Of equal value, though, perhaps, more obviously so to the scientific than to the "practical" man, is the study of the natural vegetation of the country. In a highly cultivated land like ours there are comparatively few places where the native flora remains in possession, but the mapping of the main crops which have supplanted it is nearly as useful. To become satisfactory from this point of view, the statistics of the Board of Agriculture ought to be supplemented by surveys made by trained botanists on the ground. A valuable beginning has been made under the ever-fertile stimulus of Prof. Patrick Geddes in the two sheets of a map of the plant-associations of Scotland compiled by the late Robert Smith, whose premature death last year was a loss to science. It would be a splendid thing if this map could be finished as a memorial to the brilliant young botanist in the same way as the survey of the lakes is proposed as a memorial worthy of Fred Pullar, and I am glad to learn that there is some probability of it being carried on.

Of all the other distributions which might be worked out cartographically time fails us to speak; but reference must be made, however briefly, to a few.

Geography of the Air.

With regard to Meteorology, the distribution of temperature and pressure over the British Islands for the year and for the separate months have been worked out by the experienced hand of Dr. Buchan and published both in separate memoirs and in the "Meteorological Atlas," edited by Dr. Buchan and Dr. Herbertson. But such observations as the degree of cloud or of sunshine can as yet be treated only in a superficial and generalised way for want of data. Perhaps the most important and certainly the most difficult of all the atmospheric conditions to discuss fully is precipitation. It depends on so many varying conditions, such as the form and exposure of the land, the altitude above sea-level, the direction and force of the wind, the relative frequency of thunderstorms, the distance from the sea, the direction of the average paths of cyclonic storms, &c., that far more numerous and more long-continued observations are required to establish the normal condition of the country than in the case of either temperature or pressure. When we reflect that the whole water-supply of the country depends directly on rainfall, and when we remember that the value of water-power made available by differences of level promises to be greater in the future than it has been in the past, we can see that a study of rainfall in conjunction with configuration may prove as valuable for the localisation of the manufacturing centres of the future as the geological survey was for those of the present.

Thanks to the remarkable foresight and the untiring exertions of the late Mr. Symons, the volunteer rainfall observers of this country have been encouraged to organise their efforts, and by working on a common plan have accumulated within the last forty years a mass of observations unrivalled for number and completeness in any other land. But as yet the difficulties in the way of constructing a map of normal rainfall on an adequate scale have not been overcome, and much experimental work will probably be necessary before it can be accomplished. To

this task it is my ambition to devote myself. I may be permitted to state that Scotland is far behind England or Wales in the number of rainfall stations per square mile. Thus there is, roughly, one rain-observing station for every 20 square miles of England, one for every 30 square miles of Wales, but only one for every 67 square miles of Scotland, and one for every 170 square miles of Ireland.

Rainfall observations only tell the amount of available water; the configuration of the stream beds must be considered in determining water-power. The only country I know where the horse-power of the rivers has been measured and mapped is Finland, but of course individual rivers, such as the Mississippi, Rhine, Seine, and Thames, have been thoroughly studied. Before many decades have passed it will be a necessary element in the surveys of all countries, though at present the available data are few and scattered.

Population Maps.

In considering human geography we come to the most interesting and least occupied field of research. Until Mr. Bosse constructed his beautiful maps of the density of population of Scotland and England we had absolutely no cartographical representation of the true distribution of people over the land. To map population by counties gives a very poor idea of the truth, for in such counties as Yorkshire or Perthshire there are large areas entirely without inhabitants, and small areas where the population is very dense. Mr. Bosse's maps were made on the principle of leaving blank all the land on which there were no dwelling houses, and so obtaining a close approximation to the true density of population of the inhabited area. For Scotland his map shows at once that it is a function of configuration. It shows the densely peopled lowland plain, the less densely peopled coast-strip surrounding the country, and the least densely peopled valleys running inland into the great uninhabited areas. The population map of England, on the other hand, shows an absolutely startling relation to the geological structure, which in turn is closely related to the configuration. We are not astonished to see the centres of densest population coinciding with the Coal Measures, but it is both surprising and instructive to see how the density of population runs parallel to the strike of the Secondary and Tertiary rocks of south-eastern England, a band of the lightest population following each outcrop of chalk and limestone, a band of dense population following each belt of sandstone or clay.

Anthropo-geography teems with fascinating subjects of research. The admirable investigations in the West of Ireland on the physical anthropology of the people might well be extended to the whole country outside the great towns, where all evidence of place of origin and original character is speedily lost. Good work has been done in this way by the Ethnographic Survey promoted by a committee of this Association, and a committee of the Royal Scottish Geographical Society has rendered great aid to the Ordnance Survey in the cognate study of the place-names of Scotland.

The distribution of religion, even in the three typical forms of Anglican, Presbyterian, and Roman Catholic—forms so typical as to be, broadly speaking, national—is most imperfectly known. The objection to a religious census is one which is somewhat difficult of comprehension in Scotland, and too polemic for sober discussion in England. But a few of the problems are worth being worked out by individuals. The curious islands of Roman Catholic continuity in Lancashire, the Hebrides and the Highlands can probably be related simply enough to the configuration of the country and the means of communication as influencing free movement of people at critical periods of history. There are many interesting points as to the geographical distribution of surnames, the relation of characteristic literature or poetry to specific areas, things small in themselves, but capable of exercising very far-reaching influence if systematically worked out.

Geographical Synthesis.

Granted that the subsidiary surveys have been made and the results put in a strictly comparable form, the central problem remains—the synthesis of the complete geography of the country. This can perhaps be solved best by comparing the maps of the various distributions in the proper order, and seeing how far they are related to one another. For the general discussion the Ordnance Map on the scale of one inch to a mile should be used, and each natural region ought properly to be treated by itself, but as a matter of practical convenience it would probably be found best to select either the artificial boundaries of counties or the still more arbitrary lines bounding sheets of the map. Whatever small area is taken as the unit of description, it should be treated in such a way as to seek for and prove or disprove the existence of any control exercised by the form of the land and its geological character on the outcrops of the rocks, the nature of the soil, the course of the rivers, the temperature and movements of the air, the rainfall, the vegetation and agriculture, the distribution of population, the sites of towns, villages, and isolated dwellings, the roads, railways and harbours, the birth-rate and death-rate, and on the progressive changes in all these conditions which are shown in the discussion of the statistics collected annually or decennially. When such unit areas are worked out individually the results can easily be combined and condensed into a geographical description that will be complete, well balanced, and symmetrical. The work is practicable; it requires only time, money, direction and workers to carry it out; but although a specimen memoir, prepared by the authority of the Royal Geographical Society, met with a certain measure of approval, all attempts failed to obtain funds for making the work complete, and the scheme must await a more educated generation before it can be profitably revived in its entirety. But meanwhile this field for geographical study and research lies at the doors of every University where the subject is or may be recognised, and the labours of professors and students might be profitably directed to the completion of such memoirs for the surrounding district, gradually working further and further afield. The idea is no more new than every other "thing under the sun." Such exercises, not so elaborately planned, but the same in essentials, were ordinary subjects for theses in the universities of Sweden and Finland during the eighteenth century. To come nearer home, the local handbooks prepared for successive meetings of the British Association are frequently very fair examples of the geographical description of a district. The essential qualities are rarer in guide-books, but we must not forget one brilliant exception, the poet Wordsworth's "Guide to the English Lakes."

It is pleasant to hear that through the encouragement of Sir John Murray the Scottish Natural History Society is taking up the systematic study of the basin of the Forth, and they will, I feel sure, give a good account of their labours. One point which must be very strongly emphasised is that a geographical treatise is distinguished from a jumble of facts mainly by the order and proportion in which the phenomena are dealt with, and by the relation of cause and effect that is established between them.

As to the utility of complete geographical descriptions, we must of course recognise their greater practical importance in new and developing countries than in old lands like our own. Yet even with us the study of the distribution of natural resources may suggest important changes, involving great redistributions of population.

A Geographical Warning.

Hitherto, except as regards exploration and cartography, the position of geography in this country has never been satisfactory. Times are changing, and even in exploration we are now only one amongst many rivals, often better equipped by education, usually in no way deficient in daring. Although the best work of several of our cartographers in Edinburgh and London need fear no comparison, we cannot conceal the fact that Germany leads the world in map-making. As regards the recognition or even the comprehension of geography by the State, by the universities and by the public, we are equally far behind our neighbours across the North Sea.

It has sometimes been hinted that the study of geography has been deliberately discouraged by politicians or by merchants because too much knowledge on the part of the public might embarrass foreign policy or lead to mercantile competition; but we surely cannot entertain such unworthy suspicions. I am inclined to attribute the neglect of the subject merely to ignorance of its nature due to imperfect education.

Two cases in which the application of geography to political and practical affairs suggests a definite course of action may be mentioned as examples. There is still one important colonial boundary entirely undelimited in a region somewhat difficult of access and still little known, where goldfields will probably be found or reported before long, and where a very serious inter-

national question may suddenly arise in a part of the world absolutely unsuspected by most people, even amongst those who interest themselves in general politics and in colonial affairs. It would cost a comparative trifle to survey the region in question, and to lay down that boundary line before the goldfields are touched, so that no international trouble could ever arise. What it may cost to postpone the matter until claims have been pegged out on debatable land, the British Guiana and Venezuela arbitration, the Alaska difficulty, and South Africa are there to tell us. It would be interesting to calculate, now that the cost of a week of fighting is known, the saving in pennies on the income tax that would have accrued from a survey of South Africa if that had been carried out as an imperial duty when Cape Colony was settled. I do not for a moment suggest that a survey would have prevented the war; but it is not unreasonable to believe that it would have shortened it by some months. In this connection it is satisfactory to know that a valuable report has been drawn up by a Committee of the British Association, presided over by Sir Thomas Holdich, embodying a scheme for the systematic survey of British protectorates.

The second example comes nearer home. The utilisation of wind- and water-power must increase in importance as mineral fuel diminishes in amount or increases in price. Wind- and water-power will never fail as long as the sun shines and the land remains higher than the sea; but what may fail unless timely precautions are taken is the power of utilising them for the benefit of the community at large. Are the existing laws as to water-rights, and the absence of laws as to the utilisation of wind desirable and satisfactory? The usual answer to such questions is, "Why trouble about that just now? These matters are not urgent, other things are." That argument is answerable for many disasters. The inevitable is in many if not in most cases simply another name for the unforeseen. It is inevitable that the country will be impoverished if the utilisation of wind- and water-power and the transport of that power by electricity are not wisely safeguarded and provided for; but when a survey of our resources, the circulation of the air over our islands, and the effects produced by the interposition of the mountains, plateaus, and valleys upon it, plainly points to the possibility of such a trouble, it only becomes inevitable as a result of culpable negligence.

These two examples, which will not strike anyone whose mind is wholly occupied in paying the penalties of old neglect, illustrate my contention that a complete geographical description based on full investigation is of the highest and most urgent importance, not for this country only, but for the Empire, and for every country in the world.

Nor is it the land alone which claims attention. It is of the utmost importance to investigate and evaluate the resources of the surrounding seas. The recent International Conference for the exploration of the sea held at Christiania formulated a scheme of research which has been taken up enthusiastically by Belgium, Holland, Germany, Denmark, Russia, Sweden and Norway. Its object is to place the fisheries of Northern Europe on a scientific basis, and to make for that purpose a comprehensive survey of the sea, which will prove of high value to meteorology, and through it to agriculture as well. The recent work by Mr. H. N. Dickson on the circulation of the surface waters of the North Atlantic in conjunction with similar work by Prof. Pettersson in Sweden shows how hopeful such researches are from the purely scientific standpoint, and their practical importance is no less. It remains with our Government to show that this country is not indifferent to an opportunity, such as has never presented itself before, of placing one of our great national industries on a basis of scientific knowledge. This is in my belief one of the cases in which the expenditure of thousands now will mean the saving of millions a few years hence.

It is magnificent to send out polar expeditions, and they speak volumes for the greatness of the human mind that can give itself to the advancement of knowledge for the sake of knowledge, knowing that it will bring no material gain; and I trust that such a spirit will continue to manifest itself until no spot of Earth, no land however cold or hot, no depth of sea, no farthest limit of the atmosphere remains unsearched and its lesson unlearnt. But I insist that the full study of our own country is on a totally different footing. Magnificent it may be, too, but sternly practical, since it is absolutely essential for our future well-being, and even for the continuance of the nation as a Power amongst the States of the world. Still, there is every probability that such work will be neglected until the events which it should avert are upon us, and then it will be too late to make provisions which now could be done cheaply, easily, and effectively.

A Proposed Remedy.

The few attempts which have been made in this country to promote the study of geography or to diminish the discouragements to geographical research have had but slight success. Much has been done to improve geographical teaching by the Royal Geographical Society, the Royal Scottish Geographical Society, the Geographical Association, this Section of the British Association, and other bodies; but that is not my theme. I refer to the little that has been done towards the elaboration of a geographical theory and the elucidation of geographical processes. Amongst the not inconsiderable number of teachers of geography in the Universities and Colleges of Great Britain there is not one man who receives a salary on which he can live in decent comfort so as to devote all his time, or a substantial part of it, to geographical research; and the same is true of every official of all the geographical societies. Not one is paid an income sufficient to enable him to devote the time not occupied by mechanical routine to any other purpose than supplementing his income by outside work—writing text-books, correcting examination papers, perhaps even practising journalism. If by an effort and the sacrifice of some of the comforts considered necessary by most people of the professional classes he devotes a few odd hours now and then to some original research, he finds very few to consider it seriously; some friendly expressions of opinion possibly, but scarcely a reader; and it counts for nothing, save, perhaps, in enhancing the reputation of his country in other lands where scientific work, no matter in what department, is valued in a due degree. All this must be changed before much progress can be made. No doubt a giant of genius would ignore all obstacles and pursue his work regardless of recognition; but such giants are not to be looked for many times in a century. It should be made possible for a man of fair abilities to receive as much opportunity, encouragement, recognition and reward for good work in geography as for good work, let us say, in chemistry or electricity. That is all that can reasonably be asked, and that is what is freely accorded in other countries where the status of the man of science is higher than it is with us. It is here that help may be hoped for from the Scottish Universities in the strength of their new endowments. If a Chair of Geography were instituted with the purpose of promoting research first and teaching afterwards, properly equipped with books, maps, and apparatus, and held on the understanding that no outside work was to be undertaken, something might yet be done to restore our country to the position it held a century and a half ago, when a text-book of geography was published without a thought of sarcasm, containing a frontispiece representing "Britannia instructing Europe, Asia, Africa, and America in the Science of Geography."

SECTION H.

ANTHROPOLOGY.

OPENING ADDRESS BY PROF. D. J. CUNNINGHAM, M.D., D.SC., LL.D., D.C.L., F.R.S., PRESIDENT OF THE SECTION.

TWENTY-FIVE years have passed since the British Association met in Glasgow. This is a long time to look back upon, and yet the period appears short when measured by the great advance which has taken place in almost all branches of knowledge. Anthropology has shared in the general progress. The discoveries made within its confines may not have been so startling, nor yet have had such a direct influence upon the material welfare of the people, as in the case of other fields of scientific study, but its development has been steady and continuous, and it has grown much in public estimation.

At the Glasgow meeting of the Association in 1876 Anthropology held a subsidiary position. It only ranked as a Department, although it gained a special prominence through having Alfred Russel Wallace as its Chairman. It was not until several years later that it became one of the recognised Sections of the Association, and attained the high dignity of having a letter of the alphabet allotted to it. But quite independently of its official status it has always been a branch of study which has been accorded a large amount of popular favour. The anthropological

meetings have, as a rule, been well attended, and the discussions, although perhaps on certain occasions somewhat discursive, have never lacked vigour or animation. Prof. Huxley, who presided over the Anthropological Department at the Dublin meeting in 1878, ascribed the popularity of the subject to the many openings which it affords for wide differences of opinion between the exponents of its numerous branches and to the innate bellicose tendency of man. As the representative of a country in which, according to the same high authority, this tendency is less strongly marked than elsewhere, and of a race which has so frequently and pointedly exhibited its abhorrence of vigorous language, I trust that my presence here as President may not react unfavourably on the interest shown in the work of the Section.

The present occasion might appear to be peculiarly appropriate for my taking stock of our anthropological possessions and summing up the numerous additions to our knowledge of "man and his doings" which have been made during the century which has just passed. Such a task, however, is surrounded with so much difficulty that I shrink from undertaking it. The scope of the subject is enormous, and the studies involved so diverse and so varied that I feel that it is beyond my power to give any comprehensive survey of its development in all its parts. I prefer therefore to confine my remarks to that province of Anthropology within which my own work has been chiefly carried on, and from this to select a subject which has for some years held a prominent place in my thoughts. I refer to the human brain and the part which it has played in the evolution of man.

One of the most striking peculiarities of man when regarded from the structural point of view is the relatively great size of his brain. Although with one or two exceptions the several parts of the brain are all more or less involved in this special development, it is the cerebral hemispheres which exhibit the preponderance in the highest degree. This characteristic of the human brain is rendered all the more significant when we consider that the cerebral hemispheres cannot be looked upon as being primitive parts of the brain. In its earliest condition the brain is composed of three simple primary vesicles, and the cerebral hemispheres appear in a secondary manner in the shape of a pair of lateral offshoots or buds which grow out from the foremost of these primitive brain-vesicles.

The offshoots which form the cerebral hemispheres are found in all vertebrates. Insignificant in size and insignificant in functional value in the more lowly forms, a steady increase in their proportions is manifest as we ascend the scale, until the imposing dimensions, the complex structure, and the marvellous functional potentialities of the human cerebral hemispheres are attained. In their development the cerebral hemispheres of man rapidly outstrip all the other parts of the brain until they ultimately usurp to themselves by far the greater part of the cranial cavity. To the predominant growth of the cerebral hemispheres is due the lofty cranial vault of the human skull; to the different degrees of development and to the different forms which they assume are largely due the variations in cranial outline in different individuals and different races—variations in the determination of which the Craniologist has laboured so assiduously and patiently.

I think that it must be manifest to everyone that the work of the Craniologist, if it is to attain its full degree of usefulness, must be founded upon a proper recognition of the relation which exists between the cranium and the brain, or, in other words, between the envelope and its contents.

The cranium expands according to the demands made upon it by the growing brain. The initiative lies with the brain, and in normal conditions it is questionable if the envelope exercises more than a very subsidiary and limited influence upon the form assumed by the contents. The directions of growth are clearly defined by the sutural lines by which the cranial bones are knit together; but these are so arranged that they admit of the expansion of the cranial box in length, in breadth, and in height, and the freedom of growth in each of these different directions has in all probability been originally determined by the requirements of the several parts of the brain.

The base or floor of the cranium, supporting as it does the brain-stem or the parts which possess the greatest phylogenetic antiquity, and which have not undergone so large a degree of modification in human evolution, presents a greater uniformity of type and a greater constancy of form in different individuals and different races than the cranial vault which covers the more highly specialised and more variable cerebral hemispheres.

To what extent and in what directions modifications in the form of the cranium may be the outcome of restrictions placed on the growth of the brain it is difficult to say. But, broadly speaking, I think we may conclude that the influence which the cranium, under normal circumstances, independently exerts in determining the various head-forms is trifling.

When we speak therefore of brachycephalic or short heads, and dolichocephalic or long heads, we are merely using terms to indicate conditions which result from individual or racial peculiarities of cerebral growth.

The brachycephalic brain is not moulded into form by the brachycephalic skull; the shape of both is the result of the same hereditary influence, and in their growth they exhibit the most perfect harmony with each other.

Craniology has been called the "spoiled child of Anthropology." It is supposed that it has absorbed more attention than it deserves, and has been cultivated with more than its share of care, while other fields of Anthropology capable of yielding rich harvests have been allowed to remain fallow. This criticism conveys a very partial truth. The cranium, as we have seen, is the outward expression of the contained brain, and the brain is the most characteristic organ of man; cranial peculiarities therefore must always and should always claim a leading place in the mind of the Anthropologist; and this is all the more imperative seeing that brains of different races are seldom available for investigation, whilst skulls in the different museums may literally be counted by thousands.

Meantime, however, the Craniologist lies buried beneath a mighty mountain of figures, many of which have little morphological value and possess no true importance in distinguishing the finer differences of racial forms. Let us take as an example the figures upon which the cephalic or length-breadth index of the skull is based. The measurement of the long diameter of the cranium does not give the true length of the cranial cavity. It includes, in addition, the diameter of an air-chamber of very variable dimensions which is placed in front. The measurement combines in itself therefore two factors of very different import, and the result is thereby vitiated to a greater or less extent in different skulls. A recent memoir by Schwalbe[1] affords instructive reading on this matter. One case in point may be given. Measured in the usual way, the Neanderthal skull is placed in the dolichocephalic class; whereas Schwalbe has shown that if the brain-case alone be considered it is found to be on the verge of brachycephaly. Huxley, many years ago, remarked that "until it shall become an opprobrium to an ethnological collection to possess a single skull which is not bisected longitudinally" in order that the true proportions of its different parts may be properly determined we shall have no "safe basis for that ethnological craniology which aspires to give the anatomical characters of the crania of the different races of mankind." It appears to me that the truth of this observation can hardly be disputed, and yet this method of investigation has been adopted by very few Craniologists.

It has become too much the habit to measure and compare crania as if they were separate and distinct entities, and without a due consideration of the evolutionary changes through which both the brain and its bony envelope have passed. Up to the present little or no effort has been made to contrast those parts of the cranial wall or cavity which have been specially modified by the cerebral growth-changes which are peculiar to man. It may be assumed that these changes have not taken place to an equal extent, or indeed followed identically the same lines in all races.

Unfortunately our present knowledge of cerebral growth and the value to be attached to its various manifestations is not so complete as to enable us to follow out to the full extent investigations planned on these lines. But the areas of cerebral cortex to which man owes his intellectual superiority are now roughly mapped out, and the time has come when the effect produced upon the cranial form by the marked extension of these areas in the human brain should be noted and the skulls of different races contrasted from this point of view.

To some this may seem a return to the old doctrine of Phrenology, and to a certain extent it is; but it would be a Phrenology based upon an entirely new foundation and elaborated out of entirely new material.

It is to certain of the growth-changes in the cerebrum which I believe to be specially characteristic of man, and which un-

[1] "Studien über Pithecanthropus erectus" (Dubois). *Zeitschrift f. Morph. und Anthrop.*, Band i. Heft 1, 1899.

questionably have had some influence in determining head-forms, that I wish particularly to refer in this Address.

The surface of the human cerebrum is thrown into a series of tortuous folds or convolutions separated by slits or fissures, and both combine to give it an appearance of great complexity. These convolutions were long considered to present no definite arrangement, but to be thrown together in the same meaningless disorder as is exhibited in a dish of macaroni. During the latter half, or rather more, of the century which has just ended it has, however, been shown by the many eminent men who have given their attention to this subject that the pattern which is assumed by the convolutions, while showing many subsidiary differences, not only in different races and different individuals, but also in the two hemispheres of the same person, is yet arranged on a consistent and uniform plan in every human brain, and that any decided deviation from this plan results in an imperfect carrying out of the cerebral function. In unravelling the intricacies of the human convolutionary pattern it was very early found that the simple cerebral surface of the ape's brain in many cases afforded the key to the solution of the problem. More recently the close study of the manner in which the convolutions assume shape during their growth and development has yielded evidence of a still more valuable kind. We now know that the primate cerebrum is not only distinguished from that of all lower mammals by the possession of a distinct occipital lobe, but also by having imprinted on its surface a convolutionary design, which in all but a few fundamental details is different from that of any other order of mammals.

There are few matters of more interest to those anthropologists who make a study of the human skull than the relationship which exists between the cranium and the brain during the period of active growth of both. Up to the time immediately prior to the pushing out of the occipital lobe, or, in other words, the period in cerebral development which is marked by the transition from the quadrupedal type to the primate type of cerebrum, the cranial wall fits like a tight glove on the surface of the enclosed cerebrum. At this stage there would appear to be a growth antagonism between the brain and the cranial envelope which surrounds it. The cranium, it would seem, refuses to expand with a speed sufficient to meet the demands made upon it for the accommodation of the growing brain. In making this statement it is right to add that Hochstetter, in a carefully reasoned memoir, has recently cast doubt upon the reality of the appearances which have led to this conclusion, and at the recent meeting of the Anatomische Gesellschaft, in Bonn, Prof. Gustaf Retzius,[1] one of the numerous observers responsible for the description of the early cerebrum upon which the conclusion is based, showed some inclination to waver in his allegiance to the old doctrine. This is not the time or the place to enter upon a discussion of so technical a kind, but I may be allowed to say that whilst I fully recognise the necessity for further and more extensive investigation into this matter I do not think that Hochstetter has satisfactorily accounted for all the circumstances of the case.

When the occipital lobe assumes shape the relationship of the cranial wall to the enclosed cerebrum undergoes a complete change. The cranium expands so rapidly that very soon a wide interval is left between the surface of the cerebrum and the deep aspect of the cranial envelope within which it lies. This space is occupied by a soft, sodden, spongy meshwork, termed the subarachnoid tissue, and it is into the yielding and pliable bed thus prepared that the convolutions grow. At first the surface of the cerebral hemisphere is smooth, but soon particular areas of the cortex begin to bulge out and foreshadow the future convolutions. These suffer no growth restriction, and they assume the form of round or elongated elevations or eminences which rise above the general surface level of the cerebral hemisphere and break up its uniform contour lines in the same manner that mountain chains protrude from the surface of the globe.

As growth goes on, and as the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, the space for surface protrusions of this kind becomes more limited. The gyral elevations are now pressed together: they become flattened along their summits, and in course of time they acquire the ordinary convolutionary shapes. While this is going on the valleys or intervals between the primitive surface elevations become narrowed, and ultimately assume the linear slit-like form characteristic of the fissures. These changes occur shortly before birth, but are not fully completed until after the first few months of infancy. The final result of this process is that the convolutions come into intimate relation with the deep aspect of the cranial wall and stamp their imprint upon it.

It is obvious that certain of the later changes which I have endeavoured to portray might be ascribed to a growth antagonism between the brain and the enclosing cranium at this period. In reality, however, it is merely a process by which the one is brought into closer adaptation to the other—a using up, as it were, of superfluous space and a closer packing together of the convolutions—after the period of active cortical growth is past. Nevertheless the convolutionary pattern is profoundly affected by it, and it seems likely that in this process we find the explanation of the different directions taken by the cerebral furrows in brachycephalic and dolichocephalic heads.

The cortical elevations which rise on the surface of the early cerebrum are due to exuberant growth in localised areas. There cannot be a doubt that the process is intimately connected with the development of function in the districts concerned. We know that functions of different kinds are localised in different parts of the cortex, and when we see an area on the surface of the early cerebrum rise up in the form of an eminence we may reasonably conclude that the growth in the area concerned is the structural foundation of what will become later on a centre of functional activity of an acute kind.

A consideration of this matter gives the clue to the simple convolutions of the ape and the complex convolutions of man, and, further, it explains how the interrupted form of fissural development is one of the essential characteristics of the human brain as compared with the simian brain. Areas which rise up in the form of one long elevation on the surface of the ape's brain appear in the form of several eminences on the surface of the human brain, and fissures which appear in the form of long continuous slits in the simian cerebrum appear in the human cerebrum in several detached bits, which may or may not in the course of time run into each other and become confluent. All this is due to the greater definition, refinement, and perfection of the functions carried on in the cerebral cortex of man. It is an index of a more complete "physiological division of labour" in the human brain.

It is not necessary, for the purpose I have in view, to enter into any detail regarding the many points of difference which become evident when the cerebral surface of the ape is compared with that of man. It is more my purpose to indicate certain of the districts of cerebral cortex which have undergone a marked increase in the human brain—an increase which may be reasonably supposed to be associated with the high mental attributes of man. To us, at the present time, it is difficult to conceive how it was ever possible to doubt that the occipital lobe is a distinctive character of the simian brain as well as of the human brain, and yet at successive meetings of this Association (1860, 1861, and 1862) a discussion, which was probably one of the most heated in the whole course of its history, took place on this very point. One of our greatest authorities on animal structure maintained that the occipital lobe and the hippocampus minor—an elevation in its interior—were both peculiar to man and to him alone. Everyone has read in the "Water Babies" Charles Kingsley's delightful account of this discussion. Speaking of the Professor he says: "He held very strange theories about a good many things. He had even got up at the British Association and declared that apes had hippopotamus majors in their brains just as men have. What a shocking thing to say; for if it were so, what would become of the faith, hope and charity of immortal millions? You may think that there are other more important differences between you and an ape, such as being able to speak, and make machines, and know right from wrong, and say your prayers, and other little matters of that kind; but that is a child's fancy." In the light of our present knowledge we can fully understand Prof. Huxley closing the discussion by stating that the question had "become one of personal veracity." Indeed, the occipital lobe, so far from being absent, is developed in the ape to a relatively greater extent than in man, and this constitutes one of the leading positive distinctive characters of the simian cerebrum. Measured along the mesial border, the percentage length of the occipital lobe to the total length of the cerebrum in the baboon, orang, and man is as follows:—

Baboon	29·7
Orang	23·2
Man	21·2

[1] Anatomische Gesellschaft, Bonn, May 21, 1901. Gustaf Retzius, "Transitorische Furchen des Grosshirns."

But these figures do not convey the full extent of the predominance of the occipital lobe in the ape. The anterior border of the lobe grows forwards beyond its proper limits, and pushes its way over the parietal lobe which lies in front, so as to cover over a portion of it by an overlapping lip termed the occipital operculum. There is not a trace of such an arrangement in the human brain, and even in the anthropoid ape the operculum has become greatly reduced. Indeed, in man there is exactly the reverse condition. The great size of the parietal lobe is a leading human character, and it has partly gained its predominance by pushing backwards so as to encroach, to some extent, upon the territory which formerly belonged to the occipital lobe.[1] A great authority[2] on the cerebral surface refers to this as a struggle between the two lobes for surface extension of their respective domains. "In the lower apes," he says, "the occipital lobe proves the victor: it bulges over the parietal lobe as far as the first annectant gyrus. Already, in the orang, the occipital operculum has suffered a great reduction; and in man the victory is on the side of the parietal lobe which presses on the occipital lobe and begins, on its part, to overlap it." Now that so much information is available in regard to the localisation of function in the cerebral cortex, and Flechsig has stimulated our curiosity in regard to his great "association areas" in which the higher intellectual powers of man are believed to reside, it is interesting to speculate upon the causes which have led to the pushing back of the scientific frontier between the occipital and parietal cerebral districts.

The parietal lobe is divided into an upper and a lower part by a fissure, which takes an oblique course across it. Rudinger,[3] who studied the position and inclination of this fissure, came to the conclusion that it presents easily determined differences in accordance with sex, race and the intellectual capacity of the individual. He had the opportunity of studying the brains of quite a number of distinguished men, amongst whom were Bischoff of Bonn, Döllinger of Munich, Tiedemann of Heidelberg, and Liebig of Munich, and he asserts that the higher the mental endowment of an individual the greater is the relative extent of the upper part of the parietal lobe.

There is absolutely no foundation for this sweeping assertion. When the evolutionary development of the parietal part of the cerebral cortex is studied exactly the reverse condition becomes manifest. It is the lower part of the parietal lobe which in man, both in its early development and in its after growth, exhibits the greatest relative increase. Additional interest is attached to this observation by the fact that recently several independent observers have fixed upon this region as one in which they believe that a marked exuberance of cortical growth may be noted in people of undoubted genius. Thus Retzius has stated that such was the case in the brains of the astronomer Hugo Gyldén,[4] and the mathematician Sophie Kovalevsky;[5] Hansemann[6] has described a similar condition in the brain of Helmholtz; and Guszman[7] in the brain of Rudolph Lenz, the musician. Some force is likewise added to this view by Flechsig, who, in a recent paper,[8] has called attention to the fact that within this district there are located two of his so-called "Terminalgebiete," or cortical areas, which attain their functional powers at a later period than those which lie around them, and which may therefore be supposed to have specially high work to perform.

Without in any way desiring to throw doubt upon the observations of these authorities, I think that at the present moment it would be rash to accept, without further evidence, conclusions which have been drawn from the examination of the few brains of eminent men that have been described. There cannot be a doubt that the region in question is one which has extended greatly in the human brain, but the association of high intellect with a special development of the region is a matter on which I must confess I am at present somewhat sceptical.

But it is not only in a backward direction that the parietal lobe in man has extended its territory. It has likewise increased in a downward direction. There are few points more striking than this in the evolution of the cerebral cortex of man. In order that I may be able to make clear the manner in which this increase has been brought about, it will be necessary for me to enter into some detail in connection with the development of a region of cerebral surface termed the *insular district*. The back part of the frontal lobe is also involved in this downward extension of surface area, and, such being the case, it may be as well to state that the boundary which has been fixed upon as giving the line of separation between the parietal and frontal districts is purely artificial and arbitrary. It is a demarcation which has no morphological significance, whilst from a physiological point of view it is distinctly misleading.

The insular district in the fœtal brain is a depressed area of an elongated triangular form. The general surface of the cerebrum occupies, all round about it, a more elevated plane, and thus the insula comes to be bounded by distinct walls, like the sides of a shallow pit dug out in the ground. The upper wall is formed by the lower margins of the frontal and parietal lobes, the lower wall by the upper margin of the temporal lobe, and the front wall by the frontal lobe. From each of these bounding walls a separate portion of cerebral cortex grows, and these gradually creep over the surface of the insula so as to overlap it, and eventually completely cover it over and exclude it from the surface, in the same way that the lips overlap the teeth and gums. That which grows from above is called the *fronto-parietal operculum*, while that which grows from below is termed the *temporal operculum*. These appear very early, and are responsible for closing over more than the hinder three-fourths of the insula. The lower or temporal operculum is in the first instance more rapid in its growth than the upper or fronto-parietal operculum, and thus it comes about that when their margins meet more of the insula is covered by the former than by the latter. So far the development is apparently precisely similar to what occurs in the ape. The slit or fissure formed by the approximation of the margins of these two opercula is called the Sylvian fissure, and it constitutes a natural lower boundary for the parietal and frontal lobes which lie above it. At first, from the more energetic growth of the lower temporal operculum, this fissure slants very obliquely upwards and backwards, and is very similar in direction to the corresponding fissure in the brain of the ape. But in the human brain this condition is only temporary. Now begins that downward movement of the parietal lobe and back part of the frontal lobe to which reference has been made. The upper or fronto-parietal operculum, in the later stages of fœtal life and the earlier months of infancy, enters into a growth antagonism with the lower or temporal operculum, and in this it proves the victor. The margins of the two opercula are tightly pressed together, and, slowly but surely, the fronto-parietal operculum gains ground, pressing down the temporal operculum, and thus extending the territory of the frontal and parietal districts. This is a striking process in the brain development of man, and it results in a depression of the Sylvian fissure or the lower frontier line of the frontal and parietal lobes. Further, to judge from the oblique direction of the Sylvian fissure in the brain of the ape, the process is peculiar to man; in the simian brain there is no corresponding increase in the area of cerebral cortex under consideration.

I do not think that it is difficult to account for this important expansion of the cerebral surface. In the fore part of the region involved are placed the groups of motor centres which control the muscular movements of the more important parts of the body. These occupy a broad strip of the surface which stretches across the whole depth of the district concerned. Within this are the centres for the arm and hand, for the face, the mouth and the throat, and likewise, to some extent, the centre for speech. In man certain of these have undoubtedly undergone marked expansion. The skilled movements of the hands, as shown in the use of tools, in writing, and so on, have not been acquired without an increase in the brain mechanism by which these are guided. So important, indeed, is the part played by the human hand as an agent of the mind, and so perfectly is it adjusted with reference to this office, that there are many who think that the first great start which man obtained on the path

[1] It is necessary to emphasise this point, because in Wiedersheim's "Structure of Man" we are told that in man there is a preponderance of the occipital lobe, and that the parietal lobe is equally developed in man and anthropoids.

[2] Eberstaller, *Wiener Medizinische Blätter*, 1884, No. 19, p. 581.

[3] "Beiträge zur Anatomie und Embryologie," als Festgabe, Jacob Henle, 1882.

[4] Retzius, *Biologische Untersuchungen*, neue Folge, viii. 1898, "Das Gehirn des Astronomen Hugo Gyldéns."

[5] Retzius, *Biologische Untersuchungen*, neue Folge, ix. 1900, "Das Gehirn der Mathematikerin Sonja Kovalevsky."

[6] Hansemann, *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, Band xx. Heft 1, 1899, "Ueber das Gehirn von Hermann v. Helmholtz."

[7] Josef Guszman, *Anatomischer Anzeiger*, Band xix. Nos. 9 and 10, April 1901, "Beiträge zur Morphologie der Gehirnoberfläche."

[8] Flechsig, "Neue Untersuchungen über die Markbildung in den menschlichen Grosshirnlappen," *Neurologisches Centralblatt*, No. 21, 1898.

which has led to his higher development was given by the setting of the upper limb free from the duty of acting as an organ of support and locomotion. It is an old saying "that man is the wisest of animals because of his hands." Without endorsing to its full extent this view, I think that it cannot be a matter for surprise that the district of the cerebral cortex in man in which the arm-centres reside shows a manifest increase in its extent.

In the same region of cerebral cortex, but at a lower level, there are also situated the centres which are responsible for facial expression. In the ape there is a considerable degree of facial play; but this is chiefly confined to the region of the lips; and the muscles of the face, although present in greater mass, show comparatively little of the differentiation which is characteristic of the lighter and more feeble muscles in the face of man. And then as to the effect produced: These human muscles are capable of reflecting every fleeting emotion, every change of mind, and by the lines and furrows their constant use indelibly fix on the countenance the character and disposition of an individual can to some extent be read. As the power of communication between primitive men became gradually established, facial movements were no doubt largely used, not only for the purpose of giving expression to simple emotions, such as anger or joy, but also for giving point and force to the faltering speech of our early progenitors by reflecting other conditions of mind. The acquisition of this power as well as the higher and more varied powers of vocalisation must necessarily have been accompanied by an increase of cerebral cortex in the region under consideration. And in this connection it is a point well worthy of note that the area of cortex mapped out in the human brain[1] as controlling the muscles of the face, mouth, and throat is as large, if not larger than that allotted to the arm and hand,[2] and yet it is questionable if all the muscles under the sway of the former would weigh as much as one of the larger muscles (say the triceps) of the arm. This is sufficient to show that it is not muscle power which determines the extent of the motor areas in the cerebral cortex. It is the degree of refinement in the movements required, as well as the degree of variety in muscle combinations, which apparently determines the amount of ground covered by a motor centre.

Still, the increase in the amount of cerebral cortex in man due to the greater refinement of movement acquired by different groups of muscles is relatively small in comparison with the increase which has occurred in other regions from which no motor fibres are sent out, and which therefore have no direct connection with muscles.

The remarkable conclusions arrived at by Flechsig, although not confirmed and accepted in all their details, have tended greatly to clear up much that was obscure in the relations of the different districts of cerebral cortex. More particularly has he been able to apportion out more accurately the different values to be attached to the several areas of the cerebral surface. He has shown that fully two thirds of the cortex in the human brain constitute what he terms "association centres." Within these the higher intellectual manifestations of the brain have their origin, and judgment and memory have their seat. They are therefore to be regarded as the psychic centres of the cerebral cortex.

Now, it requires a very slight acquaintance with the cerebral surface to perceive that the great and leading peculiarity of the human brain is the wide extent of these higher association centres of Flechsig. Except in connection with new faculties, such as speech, there has been relatively no striking increase in the extent of the motor areas in man as compared with the cortex of the ape or the idiot, but the expansion of the association areas is enormous and the increase in the frontal region and the back part of the parietal region is particularly well marked. It is this parietal extension of surface which is chiefly responsible for the pushing down of the lower frontier of the parietal lobe and the consequent enlargement of its territory.

I have already referred to the views which have been recently urged by several independent observers, that in the men who have been distinguished during life by the possession of exceptional intellectual power, this region has shown a very special development.

It is a curious circumstance, and one which is worthy of consideration, that in the left cerebral hemisphere the Sylvian fissure or the lower boundary of the parietal lobe is more depressed than in the right hemisphere, and, as a result of this, the surface area occupied by the parietal lobe is greater on the left side of the brain than on the right side. To the physiologist it is a matter of every-day knowledge that the left cerebral hemisphere shows in certain directions a marked functional pre-eminence. Through it the movements of the right arm and right side of the body are controlled and regulated. Within it is situated also the active speech centre. This does not imply that there is no speech centre on the right side, but simply that the left cerebral hemisphere has usurped the chief, if not the entire, control of this all-important function, and that from it are sent out the chief part, if not the whole, of the motor incitations which give rise to speech. The significance attached to the dominant power of the left hemisphere receives force from the now well-established fact that in left-handed individuals the speech function is also transferred over to the right side of the brain. To account for this functional preeminence of the left cerebral hemisphere numerous theories have been elaborated. The interest attached to the subject is very considerable, but it is impossible on the present occasion to do more than indicate in the briefest manner the three views which have apparently had the widest influence in shaping opinion on this question. They are: (1) that the superiority of the left cerebral hemisphere is due to its greater weight and bulk; (2) that it may be accounted for by the greater complexity of the convolutions on the left brain and the fact that these make their appearance earlier on the left side than on the right side; (3) that the explanation lies in the fact that the left side of the brain enjoys greater advantages in regard to its blood supply than the right side.

Not one of these theories when closely looked into is found to possess the smallest degree of value. Braune[1] has shown in the most conclusive manner that if there is any difference in weight between the two hemispheres it is a difference in favour of the right and not of the left hemisphere; and I may add from my own observations that this is evident at all periods of growth and development. Equally untrustworthy are the views that have been put forward as to the superiority of the left hemisphere from the point of view of convolutionary development. I am aware that it is stated that in two or three cases where the brains of left-handed people have been examined this superiority was evident on the right hemisphere. This may have been so; I can only speak for the large percentage of those who are right-handed; and I have never been able to satisfy myself that either in the growing or fully developed brain is there any constant or marked superiority in this respect of the one side over the other; and I can corroborate Ecker (*Archiv für Anthropologie*, 1868, Bd. cxi.) in his statement that there is no proof that the convolutions appear earlier on the one side than the other. The theory that an explanation is to be found in a more generous blood supply to the left hemisphere is more difficult to combat, because the amount of blood received by each side of the brain depends upon two factors, viz., the physical conditions under which the blood-stream is delivered to the two hemispheres and the calibre of the arteries or tubes of supply. Both of these conditions have been stated to be favourable to the left hemisphere. It is a matter of common anatomical knowledge that the supply pipes to the two sides of the brain are laid down somewhat differently, and that the angles of junction, &c., with the main pipe are not quite the same. Further, it is true that the blood-drains which lead away the blood from the brain are somewhat different on the two sides. Whether this would entail any marked difference in the blood-pressure on the two sides I am not prepared to say. This could only be proved experimentally; but, taking all the conditions into consideration, I am not inclined to attach much importance to the argument It is easy to deal with the loose statements which have been made in regard to the size of leading supply pipe (viz., the internal carotid artery). It passes through a bony canal in the floor of the cranium on its way into the interior of the cranial box. Its size can therefore be accurately gauged by measuring the sectional area of this bony tunnel on each side.

[1] See diagram in Schäfer's article on the "Cerebral Cortex" in his recent work on physiology.

[2] The comparison only refers to surface area, and this is not an absolutely true criterion of the relative amount of cortex in each region. The arm-centre has a large amount of cortex stowed away within the fissure of Rolando in the shape of inter-locking gyri which is not taken into account in a measurement confined to the superficial surface area. Still, this does not to any great degree detract from the argument which follows, seeing that the discrepancy is still sufficiently marked.

[1] "Das Gewichtsverhältniss der rechten zur linken Hirnhälfte beim Menschen" (*Archiv für Anat.*).

This I have done in twenty-three skulls chosen at random, and the result shows that considerable differences in this respect are to be found in different skulls. These discrepancies, however, are sometimes in favour of the one side and at other times in favour of the other side; and when the combined sectional area for all the skulls examined was calculated it was, curiously enough, found to be 583½ sq. mm. for the left side and 583 sq. mm. for the right side.

Leaving out of count the asymmetry in the arrangement of the convolutions in the two hemispheres, which cannot by any amount of ingenuity be twisted into such a form as to give a structural superiority to one side more than the other, the only marked difference which appears to possess any degree of constancy is the increase in the territory of the left parietal lobe produced by the more marked depression of its lower frontier line (Sylvian fissure). That this is in any way associated with right-handedness or with the localisation of the active speech centre in the left hemisphere I am not prepared to urge, because the same condition is present in the ape. It is true that some authorities[1] hold that the ape is right-handed as well as man, but in the gardens of the Royal Zoological Society of Ireland I have had a long and intimate experience of both anthropoid and lower apes, and I have never been able to satisfy myself that they show any decided preference for the use of one arm more than the other.

That differences do exist in the more intimate structural details of the two hemispheres, which give to the left its functional superiority, there cannot be a doubt; but these have still to be discovered. Bastian has stated that the grey cortex on the left side has a higher specific gravity, but this statement has not as yet received corroboration at the hands of other observers.

I have already mentioned that man's special endowment, the faculty of speech, is associated with striking changes in that part of the celebral surface in which the motor centre for articulate speech is located. It is questionable whether the acquisition of any other system of associated muscular movements has been accompanied by a more evident cortical change. The centre in question is placed in the lower and back part of the frontal lobe. We have seen that the insular district is covered over in the hinder three-fourths of its extent by the fronto-parietal and temporal opercula, and thus submerged below the surface and hidden from view. The brain of the ape and also of the microcephalic idiot with defective speech goes no further in its development. The front part of the insular district remains uncovered and exposed to view on the surface of the cerebrum. In man, however, two additional opercula grow out and ultimately cover over the fore part of the insula. These opercula belong to the lower and back part of the frontal lobe, and are to be looked upon as being more or less directly called into evidence in connection with the acquisition of articulate speech.

The active speech centre is placed in the left cerebral hemisphere. We speak from the left side of the brain, and yet when the corresponding region[2] on the right side is examined it is found to go through the same developmental steps.

The stimulus which must have been given to general cerebral growth in the association areas by the gradual acquisition of speech can hardly be exaggerated.

During the whole course of his evolution there is no possession which man has contrived to acquire which has exercised a stronger influence on his higher development than the power of articulate speech. This priceless gift, "the most human manifestation of humanity"—(Huxley)—was not obtained through the exertions of any one individual or group of individuals. It is the result of a slow process of natural growth, and there is no race, no matter how low, savage or uncultured, which does not possess the power of communicating its ideas by means of speech. "If in the present state of the world," says Charma, "some philosopher were to wonder how man ever began to build those houses, palaces and vessels which we see around us, we should answer that these were not the things that man began with. The savage who first tied the branches of shrubs to make himself a shelter was not an architect, and he who first floated on the trunk of a tree was not the creator of navigation." And so it is with speech. Rude and imperfect in its beginnings, it has gradually been elaborated by the successive generations that have practised it.

The manner in which the faculty of speech originally assumed shape in the early progenitors of man has been much discussed by Philologists and Psychologists, and there is little agreement on the subject. It is obvious that all the more intelligent animals share with man the power of giving expression to certain of the simpler conditions of mind both by vocal sounds and by bodily gestures. These vocal sounds are of the interjectional order, and are expressive of emotions or sensations. Thus the dog is said, as a result of its domestication, to have acquired the power of emitting four or five different tones, each indicative of a special mental condition and each fully understood by its companions. The common barn-door fowl has also been credited with from nine to twelve distinct vocal sounds, each of which is capable of a special interpretation by its fellows or its chickens. The gestures employed by the lower animals may in certain cases be facial, as expressed by the grimaces of a monkey, or changes in bodily attitude, as we see continually in the dog.

I think that it may not be unreasonably inferred that in the distant past the remote progenitors of man relied upon equally lowly means of communicating with their fellows, and that it was from such humble beginnings that speech has been slowly evolved.

There cannot be a doubt that this method of communicating by vocal sounds, facial expression and bodily gestures is capable of much elaboration; and, further, it is possible, as some hold, that it may have attained a considerable degree of perfection before articulate speech began to take form and gradually replace it. Much of it indeed remains with us to the present day. A shrug of the shoulders may be more eloquent than the most carefully prepared phrase; an appropriate expression of face, accompanied by a suitable ejaculation, may be more withering than a flood of invective. Captain Burton tells us of a tribe of North American Indians whose vocabulary is so scanty that they can hardly carry on a conversation in the dark. This and other facts have led Mr. Tylor, to whom we owe so much in connection with the early history of man, to remark: "The array of evidence in favour of the existence of tribes whose language is incomplete without the help of gesture-signs, even for things of ordinary import, is very remarkable"; and, further, "that this constitutes a telling argument in favour of the theory that gesture-language is the original utterance of mankind out of which speech has developed itself more or less fully among different tribes." It is a significant fact also, as the same author points out, that gesture-language is, to a large extent, the same all the world over.

Many of the words employed in early speech were undoubtedly formed, in the first instance, through the tendency of man to imitate the natural sounds he heard around him. To these sounds, with various modifications, was assigned a special conventional value, and they were then added to the growing vocabulary. By this means a very decided forward step was taken, and now primitive man became capable of giving utterance to his perceptions by imitative sounds.

Max Müller, although bitterly opposed to the line of thought adopted by the "Imitative School" of philologists, has expressed their views so well that I am tempted to use the words he employed in explaining what he satirically branded as the "Bow-wow Theory." He says: "It is supposed that man, being yet mute, heard the voices of the birds, dogs, and cows, the roaring of the sea, the rustling of the forest, the murmur of the brook, and the whisper of the breeze. He tried to imitate these sounds, and finding his mimicking cries useful as signs of the object from which they proceeded, he followed up the idea and elaborated language."

Hood[1] humorously and unconsciously illustrates this doctrine by a verse descriptive of an Englishman, ignorant of French, endeavouring to obtain a meal in France:—

"'Moo!' I cried for milk;
If I wanted bread
My jaws I set agoing;
And asked for new-laid eggs
By clapping hands and crowing."

[1] Ogle, "On Dextral Preeminence," *Trans.* Med. Chirurg. Soc., 1871; Aimé Père, "Les Courbures latérales normales au rachis humain." (Toulouse, 1900.)

[2] Rudinger and others have tried on very unsubstantial grounds to prove that there is a difference in this region on the two sides of the brain. There is, of course, as a rule, marked asymmetry; but I do not think that it can be said with truth that the cortical development of the region is greater on the left side than on the right.

[1] Quoted from "The Origin of Language," by Hensleigh Wedgwood, 1866.

But, although much of early articulate speech may have arisen by the development of interjectional sounds and the reproduction, by the human vocal organs, of natural sounds, it is very unlikely that these afforded the only sources from which words were originally derived. Romanes insists upon this, and, in support of his argument, refers to cases where children invent a language in which apparently imitative sounds take no part. He likewise alludes to the well-known fact that deaf mutes occasionally devise definite sounds which stand for the names of friends. In the light of such evidence, he very properly asks, "Why should it be held impossible for primitive man to have done the same?"

The value of spoken language, as an instrument of thought, is universally admitted, and it is a matter incapable of contradiction that the higher intellectual efforts of man would be absolutely impossible were it not for the support which is afforded by articulate speech. Darwin expresses this well when he says: "A complex train of thought can no more be carried on without the aid of words, whether spoken or silent, than a long calculation without the use of figures or symbols." Such being the case, I think we may conclude that the acquisition of speech has been a dominant factor in determining the high development of the human brain. Speech and mental activity go hand in hand. The one has reacted on the other. The mental effort required for the coining of a new word has been immediately followed by an increased possibility of further intellectual achievement through the additional range given to the mental powers by the enlarged vocabulary. The two processes, mutually supporting each other and leading to progress in the two directions, have unquestionably yielded the chief stimulus to brain development.

More than one Philologist has insisted that "language begins where interjection ends." For my part I would say that the first word uttered expressive of an external object marked a new era in the history of our early progenitors. At this point the simian or brute-like stage in their developmental career came to an end and the human dynasty endowed with all its intellectual possibilities began. This is no new thought. Romanes clearly states that in the absence of articulation he considers it improbable that man would have made much psychological advance upon the anthropoid ape, and in another place he remarks that "a man-like creature became human by the power of speech."

The period in the evolution of man at which this important step was taken is a vexed question and one in the solution of which we have little solid ground to go upon beyond the material changes produced in the brain and the consideration of the time that these might reasonably be supposed to take in their development.

Darwin was inclined to believe that articulate speech came at an early period in the history of the stem-form of man. Romanes gives a realistic picture of an individual decidedly superior to the anthropoid ape, but distinctly below the existing savages. This hypothetical form, half-simian, half-human, was, according to his sponsor, probably erect; he had arrived at the power of shaping flints as tools, and was a great adept at communicating with his fellows by gesture, vocal tones, and facial grimaces.

With this accomplished ancestor in his mental eye it is not surprising that Romanes was inclined to consider that articulate speech may have come at a later period than is generally supposed.

At the time that Romanes gave expression to these views he was not acquainted with the very marked structural peculiarities which distinguish the human brain in the region of the speech centre. I do not refer to the development of the brain in other districts, because possibly Romanes might have held that the numerous accomplishments of his speechless ancestor might be sufficient to account for this; I merely allude to changes which may reasonably be held to have taken place in direct connection with the gradual acquisition of speech.

These structural characters constitute one of the leading peculiarities of the human cerebral cortex, and are totally absent in the brain of the anthropoid ape and of the speechless microcephalic idiot.

Further, it is significant that in certain anthropoid brains a slight advance in the same direction may occasionally be faintly traced, whilst in certain human brains a distinct backward step is sometimes noticeable. The path which has led to this special development is thus in some measure delineated.

It is certain that these structural additions to the human brain are no recent acquisition by the stem-form of man, but are the result of a slow evolutionary growth—a growth which has been stimulated by the laborious efforts of countless generations to arrive at the perfect coordination of all the muscular factors which are called into play in the production of articulate speech.

Assuming that the acquisition of speech has afforded the chief stimulus to the general development of the brain, and thereby giving it a rank high above any other factor which has operated in the evolution of man, it would be wrong to lose sight of the fact that the first step in this upward movement must have been taken by the brain itself. Some cerebral variation—probably trifling and insignificant at the start, and yet pregnant with the most far-reaching possibilities—has in the stem-form of man contributed that condition which has rendered speech possible. This variation, strengthened and fostered by natural selection, has in the end led to the great double result of a large brain with wide and extensive association areas and articulate speech, the two results being brought about by the mutual reaction of the one process upon the other.

SECTION I.

PHYSIOLOGY.

OPENING ADDRESS BY PROF. JOHN G. MCKENDRICK, M.D., LL.D., F.R.S., PRESIDENT OF THE SECTION.

WHEN the British Association met in Glasgow twenty-five years ago I had the honour of presiding over Physiology, which was then only a sub-section of Section D. The progress of the science during the quarter of a century has been such as to entitle it to the dignity of a Section of its own, and I feel it to be a great honour to be again put in charge of the subject. While twenty-five years form a considerable portion of the life of a man, from some points of view they constitute only a short period in the life of a science. But just as the growth of an organism does not always proceed at the same rate, so is it with the growth of a science. There are times when the application of new methods or the promulgation of a new theory causes rapid development, and there are other times when progress seems to be slow. But even in these quiet periods there may be steady progress in the accumulation of facts, and in the critical survey of old questions from newer points of view. So far as physiology is concerned, the last quarter of a century has been singularly fruitful, not merely in the gathering in of accurate data by scientific methods of research, but in the way of getting a deeper insight into many of the problems of life. Thus our knowledge of the phenomena of muscular contraction, of the changes in the secreting cell, of the interdependence of organs illustrated by what we now speak of as internal secretion, of the events that occur in the fecundated ovum and in the actively growing cell, of the remarkable processes connected with the activity of an electrical organ, and of the physiological anatomy of the central nervous organs, is very different from what it was twenty-five years ago. Our knowledge is now more accurate, it goes deeper into the subject, and it has more of the character of scientific truth. For a long period the generalisations of physiology were so vague, and apparently so much of the nature of more or less happy guesses, that our brethren the physicists and chemists scarcely admitted the subject into the circle of the sciences. Even now we are sometimes reproached with our inability to give a complete solution of physiological problem, such as, for example, what happens in a muscle when it contracts; and not long ago physiologists were taunted by the remark that the average duration of a physiological theory was about three years. But this view of the matter can only be entertained by those who know very little about the science. They do not form a just conception of the difficulties that surround all physiological investigation, difficulties far transcending those relating to research in dead matter; nor do they recollect that many of the more common phenomena of dead matter are still inadequately explained. What, for example, is the real nature of elasticity; what occurs in dissolving a little sugar or common salt in water; what is electrical conductivity? In no domain of science, except in mathematics, is our knowledge absolute; and physiology shares with the other sciences the possession of problems that, if I may use a paradox, seem to be more insoluble the nearer we approach their solution.

The body of one of the higher animals—say that of man—is a highly complex mechanism, consisting of systems of organs, of individual organs, and of tissues. Physiologists have been able to give an explanation of the more obvious phenomena. Thus

locomotion, the circulation of the blood, respiration, digestion, the mechanism of the senses, and the general phenomena of the nervous system have all been investigated, and in a general way they are understood. The same statement may be made as to the majority of individual organs. It is when we come to the phenomena in the living tissues that we find ourselves in difficulties. The changes happening in any living cell, let it be a connective tissue corpuscle, or a secreting cell, or a nerve-cell, are still imperfectly understood; and yet it is upon these changes that the phenomena of life depend. This has led the more thoughtful physiologists in recent years back again to the study of the cell and of the simple tissues that are formed from cells. Further, it is now recognised that if we are to give an adequate explanation of the phenomena of life, we should study these, not in the body of one of the lower organisms, as was at one time the fashion, where there is little if any differentiation of function—the whole body of an amœboid organism showing capacities for locomotion, respiration, digestion, &c.—but in the specialised tissue of one of the higher animals. Thus the muscle-cell is specialised for contraction, and varieties of epithelium have highly specialised functions.

But when cells are examined with the highest microscopic powers, and with the aid of the highly elaborated methods of modern histology, we do not seem to have advanced very far towards an explanation of the ultimate phenomena. There is the same feeling in the mind of the physiologist when he attacks the cell from the chemical side. By using large numbers of cellular elements, or by the more modern and fruitful methods of micro-chemistry, he resolves the cell-substance into proteids, carbohydrates, fats, saline matter and water, with possibly other substances derived from the chemical changes happening in the cell while it was alive; but he obtains little information as to how these proximate constituents, as they are called, are built up into the living substance of the cell. But if we consider the matter it will be evident that the phenomena of life depend on changes occurring in the interactions of particles of matter far too small even to be seen by the microscope. The physicist and the chemist have not been content with the investigation of large masses of dead matter, but to explain many phenomena they have had recourse to the conceptions of molecules and atoms and of the dynamical laws that regulate their movements. Thus the conception of a gas as consisting of molecules having a to-and-fro motion, first advanced by Krönig in 1856 and by Clausius in 1857, has enabled physicists to explain in a satisfactory manner the general phenomena of gases, such as pressure, viscosity, diffusion, &c. In physiology few attempts have been made in this direction, probably because it was felt that data had not been collected in sufficient numbers and with sufficient accuracy to warrant any hypothesis of the molecular structure of living matter, and physiologists have been content with the microscopic and chemical examination of cells, of protoplasm, and of the simpler tissues formed from cells. An exception to this general remark is the well-known hypothesis of Du Bois-Reymond as to the existence in muscle of molecules having certain electrical properties, by which he endeavoured to explain the more obvious electrical phenomena of muscle and nerve. The conception of gemmules by Darwin and of biophors by Weismann are examples also of a hypothetical method of discussing certain vital phenomena.

The conception, however, of the existence in living matter of molecules has not escaped some astute physicists. The subject is discussed with his usual suggestiveness by Clerk Maxwell in the article Atom in the "Encyclopædia Britannica" in the volume published in 1875, and he places before the physiologist a curious dilemma. After referring to estimates of the diameter of a molecule made by Loschmidt in 1865, by Stoney in 1868, and by Lord Kelvin (then Sir W. Thomson) in 1870, Clerk Maxwell writes:—

"The diameter and the mass of a molecule, as estimated by these methods, are, of course, very small, but by no means infinitely so. About two millions of molecules of hydrogen in a row would occupy a millimetre, and about two hundred million million million of them would weigh a milligramme. These numbers must be considered as exceedingly rough guesses; they must be corrected by more extensive and accurate experiments as science advances; but the main result, which appears to be well established, is that the determination of the mass of a molecule is a legitimate object of scientific research, and that this mass is by no means immeasurably small.

"Loschmidt illustrates these molecular measurements by a comparison with the smallest magnitudes visible by means of a microscope. Nobert, he tells us, can draw 4000 lines in the breadth of a millimetre. The intervals between these lines can be observed with a good microscope. A cube, whose side is the 4000th of a millimetre, may be taken as the *minimum visible* for observers of the present day. Such a cube would contain from 60 to 100 million molecules of oxygen or of nitrogen; but since the molecules of organised substances contain on an average about fifty of the more elementary atoms, we may assume that the smallest organised particle visible under the microscope contains about two million molecules of organic matter. At least half of every living organism consists of water, so that the smallest living being visible under the microscope does not contain more than about a million organic molecules. Some exceedingly simple organism may be supposed built up of not more than a million similar molecules. It is impossible, however, to conceive so small a number sufficient to form a being furnished with a whole system of specialised organs.

"Thus molecular science sets us face to face with physiological theories. It forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety which exists in the properties and functions of the most minute organisms.

"A microscopic germ is, we know, capable of development into a highly organised animal. Another germ, equally microscopic, becomes when developed an animal of a totally different kind. Do all the differences, infinite in number, which distinguish the one animal from the other arise each from some difference in the structure of the respective germs? Even if we admit this as possible, we shall be called upon by the advocates of pangenesis to admit still greater marvels. For the microscopic germ, according to this theory, is no mere individual but a representative body, containing members collected from every rank of the long-drawn ramification of the ancestral tree, the number of these members being amply sufficient not only to furnish the hereditary characteristics of every organ of the body and every habit of the animal from birth to death, but also to afford a stock of latent gemmules to be passed on in an inactive state from germ to germ, till at last the ancestral peculiarity which it represents is revived in some remote descendant.

"Some of the exponents of this theory of heredity have attempted to elude the difficulty of placing a whole world of wonders within a body so small and so devoid of visible structure as a germ by using the phrase structureless germs. Now one material system can differ from another only in the configuration and motion which it has at a given instant. To explain differences of function and development of a germ without assuming differences of structure is, therefore, to admit that the properties of a germ are not those of a purely material system."

The dilemma thus put by Clerk Maxwell is (first) that the germ cannot be structureless, otherwise it could not develop into a future being, with its thousands of characteristics; or (second) if it is structural it is too small to contain a sufficient number of molecules to account for all the characteristics that are transmitted. A third alternative might be suggested, namely, that the germ is not a purely material system, an alternative that is tantamount to abandoning all attempts to solve the problem by the methods of science.

It is interesting to inquire how far the argument of Clerk Maxwell holds good in the light of the knowledge we now possess. First, as regards the *minimum visible*. The smallest particle of matter that can now be seen with the powerful objectives and compensating eyepieces of the present day is between the $\frac{1}{4000000}$th and the $\frac{1}{5000000}$th of a inch, or $\frac{1}{20000}$th of a millimetre in diameter, that is to say, five times smaller than the estimate of Helmholtz of $\frac{1}{4000}$th of a millimetre. The diffraction of light in the microscope forbids the possibility of seeing still smaller objects, and when we are informed by the physicists that the thickness of an atom or molecule of the substances investigated is not much less than a millionth of a millimetre, we see how far short the limits of visibility fall of the ultimate structure of matter.

Suppose, then, we can see with the highest powers of the microscope a minute particle having a diameter of $\frac{1}{20000}$th of a millimetre, it is possible to conceive that some of the phenomena of vitality may be exhibited by a body even of such small dimensions. The spores of some of the minute objects now studied by the bacteriologist are probably of this minute size,

and it is possible that some may be so minute that they can never be seen. It has been observed that certain fluids derived from the culture of micro-organisms may be filtered through thick asbestos filters, so that no particles are seen with the highest powers, and yet those fluids have properties that cannot be explained by supposing that they contain toxic substances in solution, but rather by the assumption that they contain a greater or less number of organic particles so small as to be microscopically invisible. I am of opinion, therefore, that it is quite justifiable to assume that vitality may be associated with such small particles, and that we have by no means reached what may be called the vital unit when we examine either the most minute cell or even the smallest particle of protoplasm that can be seen. This supposition may ultimately be of service in the framing of a theory of vital action.

Weismann in his ingenious speculations has imagined such a vital unit to which he gives the name of a biophor, and he has even attempted numerical estimates. Before giving his figures let us look at the matter in another way. Take the average diameter of a molecule as the millionth of a millimetre, and the smallest particle visible as the $\frac{1}{20000}$th of a millimetre. Imagine this small particle to be in the form of a cube. Then there would be in the side of the cube, in a row, fifty such molecules, or in the cube $50 \times 50 \times 50 = 125,000$ molecules. But a molecule of organised matter contains about fifty elementary atoms. So that the 125,000 molecules in groups of about fifty would number $\frac{125000}{50} = 2500$ organic particles. Suppose, as was done by Clerk Maxwell, one half to be water; there would remain 1250 organic particles. The smallest particle that can be seen by the microscope may thus contain as many as 1250 molecules of such a substance as a proteid.

Weismann's estimates as to the dimensions of the vital unit to which he gives the name of biophor may be shortly stated. He takes the diameter of a molecule at $\frac{1}{2000000}$th of a millimetre (instead of the one millionth) and he assumes that the biophor contains 1000 molecules. Suppose the biophor to be cubical, it would contain ten in a row, or $10 \times 10 \times 10 = 1000$. Then the diameter of the biophor would be the sum of ten molecules, or $\frac{1}{2000000} \times 10 = \frac{10}{2000000}$ or $\frac{1}{200000}$th of a millimetre. Two hundred biophors would therefore measure $\frac{200}{200000}$ or $\frac{1}{1000}$ mm. or 1 μ (micron $= \frac{1}{1000}$th mm.). Thus a cube one side of which was 1 μ would contain $200 \times 200 \times 200 =$ 8,000,000 biophors. A human red blood corpuscle measures about 7·7 μ; suppose it to be cubed, it would contain as many as 3,652,264,000 biophors.

Now if the smallest particle that can be seen ($\frac{1}{20000}$th mm.) may contain 1250 molecules, let us consider how many exist in a biophor, which we may imagine as a little cube, each side of which is $\frac{1}{2000000}$th mm. There would then be five in a row of such molecules, or in the cube $5 \times 5 \times 5 = 125$ molecules; and if the half consisted of water about sixty molecules.

Let us apply these figures to the minute particles of matter connected with the hereditary transmission of qualities. The diameter of the germinal vesicle of the ovum is $\frac{1}{20}$th of a millimetre. Imagine this a little cube. Taking the diameter of an atom at $\frac{1}{10000000}$th of a millimetre, and assuming that about fifty exist in each organic molecule (proteid, &c.), the cube would contain at least 25,000,000,000,000 organic molecules. Again, the head of the spermatozoid, which is all that is needed for the fecundation of an ovum, has a diameter of about $\frac{1}{200}$ mm. Imagine it to be cubed; it would then contain 25,000,000,000 organic molecules. When the two are fused together, as in fecundation, the ovum starts on its life with over 25,000,000,000,000 organic molecules. If we assume that one half consists of water, then we may say that the fecundated ovum may contain as many as about 12,000,000,000,000 organic molecules. Clerk Maxwell's argument that there were too few organic molecules in an ovum to account for the transmission of hereditary peculiarities does not apparently hold good. Instead of the number of organic molecules in the germinal vesicle of an ovum numbering something like a million, the fecundated ovum probably contains millions of millions. Thus the imagination can conceive of complicated arrangements of these molecules suitable for the development of all the parts of a highly complicated organism, and a sufficient number, in my opinion, to satisfy all the demands of a theory of heredity. Such a thing as a structureless germ cannot exist. Each germ must contain peculiarities of structure sufficient to account for the evolution of the new being, and the germ must therefore be considered as a material system.

Further, the conception of the physicist is that molecules are more or less in a state of movement, and the most advanced thinkers are striving towards a kinetic theory of molecules and of atoms of solid matter which will be as fruitful as the kinetic theory of gases. The ultimate elements of bodies are not freely movable each by itself; the elements are bound together by mutual forces, so that atoms are combined to form molecules. Thus there may be two kinds of motion, atomic and molecular. By molecular motion is meant "the translatory motion of the centroid of the atoms that form the molecule, while as atomic motion we count all the motions which the atoms can individually execute without breaking up the molecule. Atomic motion includes, therefore, not only the oscillations that take place within the molecule, but also the rotation of the atoms about the centroid of the molecule."[1]

Thus it is conceivable that vital activities may also be determined by the *kind* of motion that takes place in the molecules of what we speak of as living matter. It may be different in kind from some of the motions known to physicists, and it is conceivable that life may be the transmission to dead matter, the molecules of which have already a special kind of motion, of a form of motion *sui generis*.

I offer these remarks with much diffidence, and I am well aware that much that I have said may be regarded as purely speculative. They may, however, stimulate thought, and if they do so they will have served a good purpose, although they may afterwards be assigned to the dust-heap of effete speculations. Meyer writes as follows in the introduction to his great work on "The Kinetic Theory of Gases," p. 4:—"It would, however, be a considerable restriction of investigation to follow out only those laws of nature which have a general application and are free from hypothesis; for mathematical physics has won most of its successes in the opposite way, namely, by starting from an unproved and unprovable, but probable, hypothesis, analytically following out its consequences in every direction, and determining its value by comparison of these conclusions with the result of experiment."

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

SIR PHILIP MAGNUS will distribute the prizes to students of the Morley Memorial College, Waterloo Road, on October 1.

THE Report of the Board of Education, reviewing the proceedings of the Board for the year which ended with last year, has been published as a Blue-book. Reference is made to the Committee appointed to consider the best means of coordinating the technological work of the Board with that at present carried on by other educational organisations. The report of the Committee was received some time ago, and is now "under consideration." It is to be hoped that the report will soon be issued and action taken upon it.

SCIENTIFIC SERIALS.

The American Journal of Science, September.—The discharge current from a surface of large curvature, by John E. Almy. It was found that the current discharging from a fine wire to a concentric cylinder is given by the equation

$$I = LaV(V - b)/r^3,$$

where I is the discharge current, V is the potential difference between the wire and cylinder, L is the length of the discharge wire, r the radius of the cylinder, b the minimum potential necessary to produce a measurable discharge, and a a constant depending upon the size of the wire, the nature of the discharging gas and the sign of the discharge.—On octahedrite and brookite from Brindletown, North Carolina, by H. H. Robinson.—On the behaviour of small closed cylinders in organ pipes, by B. Davis. When small gelatine capsules or light paper cylinders were placed in a stopped organ pipe, on sounding the pipe the cylinders immediately moved to the middle of the stationary loop and arranged themselves in rows across the pipe. The effects produced were of the same nature as the Kundt dust figures.—On a cæsium-tellurium fluoride, by H. L. Wells and

[1] Meyer, "Kinetic Theory of Gases." Translated by Baynes, London, 1899, p. 6.